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# MONTHLY WEATHER REVIEW

## OCTOBER, 1930

CONTENTS


| | Page |
|---|---|
| Excerpts from the Annual Report of the Chief of Weather Bureau for the year ending June 30, 1930. (1 chart.) C. F. Marvin | 393 |
| The great drought of 1930 in the United States—supplemental notes. A. J. Henry, Harry B. Humphrey, and B. C. Kadel. (2 figs.) | 396 |
| Drought in the Ohio Valley and water supply. W. C. Devereaux | 401 |
| Low water in the Kentucky River, 1930. (3 figs.) W. S. Winn | 401 |
| Squall lines in New Mexico. (9 figs.) Cleve Hallenbeck | 402 |
| Late tertiary climatic changes in Oregon. (5 figs.) Edwin T. Hodge | 405 |
| Meteorological investigations in Greenland during 1930–31. Leonard R. Schneider | 412 |
| Swedish expedition to the North Atlantic Gulf Stream. Leonard R. Schneider | 413 |
| Meteorological peculiarities of the Yakima Valley, Washington. Edwin H. Jones | 413 |
| The passing of the mirage locally. A. A. Justice | 414 |
| Simplified rain-intensity formulas. (2 figs.) C. E. Grunsky | 416 |
| Analysis of the precipitations of rain and snow during 1929–30, at Mount Vernon, Iowa. Willard C. Stewart | 418 |
| NOTES, ABSTRACTS, AND REVIEWS: | |
| Some problems of modern meteorology. *Reprinted.* D. Brunt | 419 |
| Exceptionally severe snowstorm of October 18–19, 1930, near Buffalo, N. Y. (2 figs.) J. H. Spencer | 422 |
| A new rainfall map of the State of Washington. O. W. Freeman | 422 |
| M. A. Giblett, 1894–1930. *Obituary.* A. J. H. | 423 |
| Sun spots and pressure distribution. R. M. Deeley | 423 |
| The bora. C. F. B. | 423 |
| City temperatures. C. F. B. | 423 |
| Rain map of Australia for 1929. C. F. B. | 423 |
| Climatological summaries for Chile for August and September, 1930. J. Bustos Navarrete. *Transl. by W. W. R.* | 423 |
| BIBLIOGRAPHY | 424 |
| SOLAR OBSERVATIONS | 424 |
| AEROLOGICAL OBSERVATIONS | 426 |
| WEATHER IN THE UNITED STATES | 427 |
| WEATHER ON THE ATLANTIC AND PACIFIC OCEANS | 429 |
| CLIMATOLOGICAL TABLES | 434 |
| CHARTS I–VI AND VIII–XI | |


UNITED STATES DEPARTMENT OF AGRICULTURE

WEATHER BUREAU

WASHINGTON, D. C.

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## CORRECTION

Monthly Weather Review:

**May**, 1930: Page 204, in the diagram (Fig. 1) the numeral "4" following "Jan.", "Feb.", and "March" should be deleted as the three lines represent *monthly* means, *not individual dates.*

September, 1930: Page 373, the author's name should be "Simson."

# MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

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OCTOBER, 1930

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## EXCERPTS FROM THE ANNUAL REPORT OF THE CHIEF OF THE WEATHER BUREAU FOR THE YEAR ENDING JUNE 30, 1930

By C. F. MARVIN

### THE UNPRECEDENTED DROUGHT OF 1930

Foremost in the minds of all during a summer like 1930 is the question, what causes such abnormal conditions? No conclusive and comprehensive answer can be given. Moreover, the answer will need to be varied and adapted more or less to particular cases. Directing our answer particularly to the extensive drought of 1930, all we can say is that these unusual conditions are best explained as a prolonged stagnation of the air over nearly the whole continental extent of the United States. In ordinary years this great blanket of atmosphere overlying the continent is in more or less active circulation. Cool air from the polar regions moves southward from time to time. This feature of circulation has been especially absent this summer. Warm air from the tropical latitudes moves northward at intervals. Air from the oceans and Gulf moves inland, and there is a more or less active and continuous interchange of these different air masses, causing the agreeable and favorable conditions that prevail in ordinary years. This circulation and interchange has been conspicuously absent for a long time during the present great drought.

During this stagnation the occasional showers and thunderstorms here and there over the drought-stricken region served only to dry out the overlying air masses. Only a part, at best, of this water is evaporated back into the free air, and with little or no moisture borne in by winds from the oceans, each successive inland shower, coupled with the stagnation and absence of general rain-causing processes, tends to further deplete the moisture supply and intensify the drought condition. It may be pointed out, also, that over most of the United States the summer heat is normally at its maximum about the last week of July. Therefore, summertime stagnation and lack of active circulation within the continental air blanket causes the absence of precipitation and permits the culmination of excessive temperatures, but the experts are unable to assign a specific cause for the prolonged stagnation.

### CYCLES AND SEASONAL WEATHER FORECASTS

The occurrence of any notable weather event, such as the drought of the summer of 1930, is always made the occasion for discussion of the possibility of predicting such happenings sufficiently far in advance to permit of steps being taken, if indeed any such are possible, to lessen the economic loss which is bound to result so long as they arrive unheralded.

Another even more futile imagination is that these untoward happenings can be caused or suppressed by man himself. For example, many letters are received urging that by the use of explosives and aerial bombardment we can cause plentiful rain. Curiously enough, another group of writers urge us to employ aerial explosives and bombardment to destroy hurricanes, tornadoes, etc. Here we have the absurd representation that by the use of exactly the same means we can supply rainfall to drought-stricken regions or we can suppress tornadoes, hurricanes, etc., which are frequently accompanied by even torrential rainfalls.

With reference to these and the possibility of future forecasting, the Weather Bureau continues to hold an entirely open mind and to seek for promising lines of attack on the problem of such forecasts, but we can not be led away from a sane and rational conservatism in these matters, either by the occurrence of great natural disasters or the confident assertions of advocates of this, that, or the other fanciful idea. In so far as a sound physical basis for seasonal forecasts is involved, the subject can be said to be still in the speculative stage. Some practical advances have been made by means of correlations, but the sum total of results attained by this method is relatively small.

The complexity of the problem is well illustrated by the weather extremes of the past year in different agricultural areas. While a great part of the United States was suffering for want of rain, western Europe was experiencing an extraordinarily wet harvest season, and in the great corn-growing region of Argentina the weather was so continuously wet as to delay the conditioning of corn for shipment overseas. It will be readily understood that until the different kinds of weather which occur simultaneously throughout the world have been satisfactorily correlated among themselves, forecasts therefor from a single factor, such as periodicity in sunspots or variations in solar radiation, can have no hope of success.

One line of attack on the problem of seasonal weather forecasts that is thought by meteorologists to offer some promise of success is that afforded by changes in the temperature of the surface waters of the oceans. It is well known that the oceans exert a pronounced influence on the climate of adjacent land areas. The character, amount, and extent of the influence depend on various circumstances, as latitude, direction of the prevailing winds, topography, and distance from the coast. Inadequacy of observations and other difficulties have hitherto operated to prevent any considerable investiga-

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tions in this field by the Weather Bureau, although some preliminary work has been done in recent years. However, as a result of the development of commerce with Latin America and the opening of the Panama Canal observations from ships have been increasing from the strategic water areas embracing portions of the Atlantic equatorial currents and the Gulf Stream.

Much has been said by many people that weather phenomena recur in cycles. Naturally this whole subject is a very complicated one, and we all recognize the ups and downs, and the frequent extremes of heat and cold, wet and dry weather phenomena. A critical study of these phenomena has failed to disclose any such orderly system of recurrences as the word "cycle" connotes in the minds of most people. Forecasts on any such basis as this will fail quite as many times as they might succeed, and even at the best the intervals between recurrences are subject to such wide changes in length of interval, and the magnitude of the extremes, although sometimes large, are frequently entirely insignificant, so that the reality of cycles is very problematical, and forecasting by means of them is as yet unsuccessful.

The subject of correlations and periodicities of weather phenomena are under continuous investigation by one or more of the experts of the bureau, in the hope of discovering useful information.

### WEATHER SERVICE FOR AIRWAYS

In previous annual reports, particularly those issued in 1927, 1928, and 1929, the bureau's service for flying activities was discussed at some length, principally from the point of view of organization and the legislation authorizing it. It seems proper at this time to indicate the general character of this service, as now organized, and to point out needs for expansion as the network of airways is still further extended.

As is well known, the Weather Bureau is charged with the duty of furnishing service for all interests—agriculture, commerce, and navigation, which last now includes the air as well as the sea. In doing this the bureau has organized a network of some 210 first-order stations, well distributed over the entire country. These stations regularly exchange reports twice daily and also keep continuous records of weather conditions for statistical and research purposes. The twice-daily reports are used in issuing summarized statements and forecasts, which are given wide dissemination by telegraph, telephone, radio, and the press. This may be called the bureau's general or primary service.

In addition, several more detailed and intensive services have been organized to meet special needs, including the protection of fruit and other crops from frost, warnings of conditions favorable for floods, forest fires, hurricanes, and other violent storms. For these services numerous second-order stations—several hundred of them—have been established at points from which experience shows that the information is needed. The reports are made by noncommissioned personnel, in accordance with prearranged schedules, or on call.

The most recently organized of these intensive services is that for flying activities on commercial airways. The bureau's authority for this service is defined in section 5 (e) of the air commerce act of 1926. In organizing the service, close cooperation is maintained with the Department of Commerce, which is charged with providing communication, lighting, and landing facilities for the airways. As a rule, detailed surveys of proposed airways are made jointly by representatives of both departments. In the course of these surveys a study is made of past records in order to determine the general character of the weather conditions that are likely to be encountered. Pilots and officials of the air-transport companies and others who are familiar with the section are consulted with a view to determining what the needs are and how to meet them. Finally, a program of service is formulated and organized Naturally, it is necessary to keep this program within the limit of funds appropriated for the purpose, and also to distribute those funds equitably and impartially to all sections of the airways system.

The basic features of the service are timely reports of current conditions and short-period forecasts. In other words, the aim is to give the pilot the weather of the "now" and the "soon to be." To do this, special observing stations are established along and near the airways. The distance between these stations varies from 5 to 10 to 100 miles, depending on the topographic and meteorological characteristics of the section. The time interval between reports also varies, this depending largely on the volume of traffic. Where flying is more or less continuous both day and night, reports are received from all observing stations on the airways once each hour, and in some cases intermediate half-hourly reports are received from the more important terminal stations. On airways having as yet but little traffic—one regular daily flight each way, for example—the reports are timed to fit the schedules. This latter type of service as a rule characterizes only the earlier stages of an airway's history. As flying increases and off-schedule flights become common, experience shows that the needs for service can be met adequately only by frequent and regular reports.

Attention is invited to the accompanying chart, which shows the airways for which service is now furnished. At about 50 of the more important terminal airports on these airways the bureau has established continuous 24-hour service, with full instrumental equipment and personnel of 4 to 7 technically trained men. At some 250 intermediate stations the observations are made by properly instructed, though not technically trained, personnel, who report the conditions as observed by eye or with comparatively simple instrumental equipment. Reports from these special stations are transmitted to the bureau's more important centers on the airways.

Naturally the prompt collection of these reports (and unless they are prompt, all the effort is wasted) requires a highly efficient communication system whose organization is a function of the airways division of the Department of Commerce. It was early found that for this particular purpose, dependence can not be placed on the ordinary commercial facilities. During the time of peak loads—that is, in the middle of the day—absolute promptness could not be guaranteed. All types of business are entitled to equal service. It was evident, therefore, that a system of communications under absolute control is necessary. This has been accomplished on some of the main airways through the installation of a printing telegraph, or teletype, circuit. The circuits consist of leased telephone lines, 500 to 800 miles in length, between terminal airports, with drops at the intermediate weather-reporting stations, each one of which has an automatic typewriter, or teletype machine. The messages are typed on these machines in sequence, the various stations following one another in rapid succession, and each message is received on tape by all other stations in the circuit. This

Chart showing commercial airways for which intensive weather service has been organized. Open circles are Weather Bureau airport stations, with continuous 24-hour service. Dots are additional stations off the airways that furnish three-hourly reports to designated centers.

UNIV. OF MICH.

system of communications is prompt and is rapidly increasing in efficiency and reliability. The Department of Commerce plans to extend it eventually to all interstate trade air routes.

All reports, whether sent by teletype, telephone, telegraph, or radio, include information concerning the following elements: General condition of sky and weather; ceiling; visibility; surface wind direction and velocity; temperature; barometric pressure; and miscellaneous conditions, such as thunderstorms, squalls, and state of landing field as affected by rain, snow, etc.

In many cases dew point is also reported, and some of the airport stations (about 45 at present) give detailed data of wind direction and velocity at various heights.

For the general condition of sky and weather no instruments are required, but certain definite terms have become standard for expressing it, such as "clear," "broken clouds," "overcast," "fog," "heavy rain," "sleet," etc. This first word in the report tells the pilot at once whether conditions are satisfactory, impossible, or simply uncertain and therefore subject to further study.

The next two items, ceiling and visibility, usually answer this question of uncertainty. For observations of ceiling at night when clouds are present the so-called "ceiling light" is in general use. A beam of light is shot upward, in some cases vertically, in others at a 45° angle, and in still others at some intermediate angle. The use of this instrument has not as yet wholly passed the experimental stage, but the consensus of opinion is that a vertically projected beam gives the best results. There is still some uncertainty also as to the most satisfactory intensity. At present 250-watt bulbs are in general use, although a higher intensity is favored by some, especially for stations in mountainous country, where high ceilings are essential for safety. In all cases the beam makes a spot of light where it strikes a cloud. This spot is more or less definite and well marked, depending on the density of the cloud mass. The height of the spot, and therefore of the ceiling, is determined by means of an alidade, or clinometer. The angular reading of this instrument, together with the known distance of the light source from the point of observation, provides the necessary data. In many cases the alidade is graduated in heights instead of degrees and thus eliminates the need of computation or the use of tables or graphs.

For observations of ceiling in the daytime, so-called "ceiling balloons" are used. These are about the size of ordinary toy balloons, although of a somewhat better quality. They are filled with hydrogen until just capable of sustaining a 40-gram weight. When released, they rise at a known and fairly constant rate. It is then only necessary to note accurately the exact time of their disappearance in the cloud. As in the case of ceiling lights, when the cloud mass is of a light and tenuous nature there is some slight uncertainty as to the exact moment of disappearance, and it is general practice to report the height at which the balloon begins to be indistinct. Ceilings are usually given only to the nearest hundred feet. Greater precision is not warranted in view of the fact that the cloud base itself varies as much or more within relatively short distances.

Observations of visibility are noninstrumental. It is customary to give the greatest distance at which conspicuous objects can be clearly seen. Whenever practicable, lights are used at night. This method is approximate only, but fortunately it is most nearly accurate at times when the information is of most importance—that is, when visibility is low. It should be stated that observations of visibility show conditions in the horizontal, not in the vertical. No attempt is made to measure vertical visibility except when clouds are low, in which case it is defined by the height of the ceiling.

These two elements—ceiling and visibility—have been dwelt on at some length for the reason that all pilots ask first for information regarding them. Many ask for nothing else if these are favorable. Whereas they were never thought of in meteorology before the days of flying, now they are among the most important working elements of the meteorologist whose duty it is to tell pilots what the weather is or is going to be.

Wind direction and velocity at the surface, temperature, dew point, and barometric pressure are all so well known, as also the instruments used in observing them, that only a passing reference is necessary. Information concerning surface wind is useful principally in connection with taking off and landing. Temperature and dew point together determine the likelihood of fog and of ice formation on the planes. Reports of pressure enable the pilots to correct their altimeters, in addition to furnishing the meteorologist with basic data for synoptic charts or weather maps.

Miscellaneous phenomena are observed directly without instruments. They include thunderstorms, line squalls, exceptionally heavy rain or snow, ice formation as reported by incoming pilots, and any other conditions a knowledge of which is useful and at times vital in determining whether or not flights should be made. Special attention is always given to this part of the reports.

For measurements of upper wind direction and velocity, so-called "pilot balloons" are in general use at airports. These balloons are about 6 inches in diameter and are made of pure rubber. Different colors are employed to give the best possible visibility against varying backgrounds of sky and cloud. The balloons, when filled with hydrogen, are about 28 to 30 inches in diameter and ascend at a nearly uniform rate of 600 feet a minute. Their ascent is watched with a theodolite, and angular readings are made each minute. By means of slide rule, portable telephone, and plotting board, computations are made while the observation is in progress, with the result that the wind conditions at various levels are known in detail within two or three minutes after the balloon disappears. For observations at night a small lantern is suspended a few feet below the balloon. Reports containing these data are received as a rule at the Weather Bureau's airport stations, where they are made available in various ways. In almost all cases the reports are posted on a bulletin board. If conditions are generally good, the pilots are usually satisfied with a reading of the bulletin; but, if conditions are uncertain in spots, individual copies are sometimes made for the pilots to take along on their flights.

Along with this organization by the Weather Bureau, the Department of Commerce has established a network of radio stations which broadcast the reports for certain airways once each hour. There are now about 40 such broadcasting stations. Some of the air transport companies have equipped their planes with receiving sets and others are doing so as rapidly as practicable. Thus, in addition to the information given at the airport stations of the bureau, the pilots receive supplementary reports while making their flights.

The broadcasts include not only reports of current conditions but also of expected changes for the next few hours. Short-range forecasts have already proved to be

a great aid, and it seems certain that, with the increased accuracy that is bound to come, they will ultimately constitute the most valuable feature of the weather service. There is some question as to most suitable period of time to include in the forecasts. Naturally the shorter the period, the more precise the forecasts; but, on the other hand, their value is limited unless they cover at least a reasonable period. As a basis for compromise, the maximum length of the great majority of flights has been chosen—that is, three to four hours.

As earlier stated, the basic material for all forecasting is the country-wide, twice-daily collection of reports which are used in constructing the well-known weather maps. The forecasts for 12 to 24 hours, based on these reports, are quite dependable but are necessarily given in general terms. What is needed is their amplification and localization. For this purpose supplementary reports from relatively small areas are required, small at any rate as compared with the country-wide, twice-daily system.

As an experiment, the period of three hours has been selected, the observations being made at 2, 5, 8, and 11 a. m. and p. m., seventy-fifth meridian time. About 110 stations are at present in this system. They transmit their reports to airways-forecast centers at Atlanta, Ga.; Cleveland, Ohio; Dallas, Tex.; Fort Crook (near Omaha), Nebr.; Oakland, Calif.; Portland, Oreg.; and Salt Lake City, Utah. The data are entered in detail on base maps, and lines of equal pressure are drawn. The maps for 8 a. m. and p. m., seventy-fifth meridian time, being based on the bureau's primary system of reports, are, of course, much more complete than are the six others. The latter are used as auxiliary to the former and serve to show the changes taking place in the areas for which the short-range forcasts are issued.

Although designed primarily for flying activities over established airways, the 3-hour system of reports and forecasts in large part also solves the problem of so-called off-airways flights. Before the organization of this system there was no provision for obtaining special reports from places not on regular routes except by special call and at the expense of the pilots desiring them. Now, however, information is fairly complete for large areas, and anyone desiring reports for cross-country flights in those areas has only to listen in at the proper times, since these summaries are regularly broadcast, as well as the hourly reports of conditions along the established airways themselves.

Thus far the need and value of short-range forecasts have been stressed. They are relatively precise and cover approximately the duration of nearly all flights. But they will never do away with the necessity of the longer-period forecasts, to which, rather, are they supplementary. The 12 to 24 hour forecasts will become increasingly important. While the individual pilot is interested in the weather for a few hours, the operations manager of an air-transport line needs to make his plans as far in advance as possible. Particularly is this true if passenger service is included.

Thus, the three main features of weather service for aeronautics are each essential to the proper functioning of the others: (1) The frequent, individual reports tell of the weather now; (2) the short-range forecasts cover the individual flights or announce the weather that is soon to be; and (3) the basic general forecasts indicate the likelihood of successful flying to-morrow. Considered in reverse order, the general forecasts form the groundwork of the entire service; they are supplemented by the more intensive shorter-period forecasts; and both of these are still further supplemented by timely reports of current conditions, which check the forecasts previously made and provide data for slight modification in them, if necessary.

Again referring to the chart, the system of airways there shown is only a beginning. Already surveys are being made by the Department of Commerce for many additional lines, and eventually the entire country will be covered. As rapidly as these airways are established the Weather Bureau, to the extent that additional appropriations permit, will organize service for them, along the lines of the present service, with such modifications in details as experience may show to be desirable. Fortunately, the cost of these extensions will be considerably less per airway mile than that of the service thus far organized, since much of the latter will give information that will meet in part the needs of the new lines.

## THE GREAT DROUGHT OF 1930 IN THE UNITED STATES—SUPPLEMENTAL NOTES

The previous paper on this subject (this REVIEW, September, 1930) was more or less incomplete owing to the uncertainty as to the end of the drought and the difficulty of quickly getting information from the field as to the progress of the drought in all sections. Several odds and ends have come to hand since the first account was printed. These will now be given:

### THE DROUGHT EXTENDS TO THE PANAMA CANAL ZONE

Mr. R. Z. Kirkpatrick, chief of surveys, Canal Zone, supplies us with the data given in the table below showing conclusively that drought was felt almost to the Equator. The shortage of water yield was at a maximum in February and reached a second maximum in August.

TABLE 1.—*Departure from the normal water yield, Chagres River and Lake Gatun, Panama Canal Zone, January–September, 1930*

| Month | Chagres River | | Net yield Gatun Lake watershed | |
|---|---|---|---|---|
| | Above | Below | Above | Below |
| | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| January | | 44 | | 39 |
| February | | 45 | | 48 |
| March | | 34 | | 47 |
| April | | 3 | 1 | |
| May | | 1 | 1 | |
| June | | 20 | | 38 |
| July | | 18 | | 26 |
| August | | 40 | | 39 |
| September | | 15 | | 26 |

—*A. J. Henry.*

## THE INFLUENCE OF TREES AND ASSOCIATED UNDERGROWTH ON THE RATE OF STREAM DISCHARGE

Because of the prolonged and almost continuous drought of the past five months many wells in near-by Maryland and Virginia communities have registered gradually falling levels of water, and several have gone dry. Springs that in any average summer season flow constantly have during the past summer ceased to flow or have flowed only more or less intermittently. The season has been an unusually favorable one for making observations on the rate of water discharge of springs and small streams and the relation of trees and other immediate vegetation to such discharge.

So far as the writer has been able to ascertain there has been published but little in the nature of like observations. One important paper, however, deserves mention, in which Bates and Henry [1] published the results of an experiment at Wagon Wheel Gap, Colo., begun in 1909 and completed 15 years later. In their study of the data recorded during this experiment they found, among other facts, that the evaporation induced by warm summer weather, combined with the water requirement of immediate plant growth, caused a rapid withdrawal of water from the surface soil. This condition they found to continue until the period of maximum heat had passed and decrease of vegetative vigor had set in.

More recently, Purton [2] has observed a marked diurnal fluctuation in the flow of a small stream near Hawthorne, Nev. Inasmuch as the rate of discharge began to decline at sunrise and before there was any marked rise in atmospheric temperature, he assumed that the fluctuation was due chiefly to transpiration of the vegetation, chiefly willows, along the stream.

During the period September 15 to October 12, inclusive, daily observations were carried on by H. B. Humphrey at his home in Cabin John, Md., on the rate of stream discharge. Lacking standard meteorologic equipment he was obliged to accept, with allowance for certain more or less constant differences in temperature and relative humidity between Washington and Cabin John, the weather records for the former station. The temperature readings taken simultaneously at the two points during the first week of October, for example, showed consecutive daily minimums of 46°, 45°, 44°, 52°, 43°, 42°, and 44°, whereas, at Cabin John, the corresponding minimum temperatures were consistently lower. Killing frosts occurred on the 5th and 6th, and these unquestionably inhibited to a marked degree the respiration activities of the trees and other vegetation in the neighborhood.

In a deep and narrow ravine, just west of his residence, runs a little stream fed by some springs at the head of the ravine. This stream flows into a small reservoir and thus furnishes water for the operation of a hydraulic ram. The distance covered by the streamlet is approximately 200 feet, and within that distance and the confines of the ravine are 32 trees of various heights, sizes, and species. The smallest of these measure 3 inches in diameter and the largest, 30 inches. In addition to the trees is a limited growth of shrubby plants such as spice bush, pawpaw, and red bud, and saplings of such tree species as beech, hickory, dogwood, oak, and maple. The stream was so well covered by low vegetation that the water loss through evaporation probably was relatively negligible.

The first observation was recorded on September 12, when it was noticed at 6 p. m. there was no water discharging from the stream into the reservoir. The following morning, at 7 o'clock, water was flowing into the reservoir at the rate of nearly 5 quarts per minute. In the late afternoon of September 13 there was a thundershower and a consequent precipitation of 1 inch of rain at Cabin John. At 12 o'clock, noon, on the 14th, the rate of stream discharge was 4 quarts per minute; at 4 p. m. it was 1.9 quarts per minute. Thereafter (Table 1) the readings were made daily at 7 a. m. and, except on September 16, at 6:15 p. m., for a total of 28 days, during which period there was no further precipitation. At 6:15 p. m. on the 16th it was raining, and no reading was made.

A glance at the table will show that, in general, there was a gradual decline in the daily maximum discharge until September 30, when, apparently because of a sharp fall in temperature there was an increase in the rate of discharge from 4.40 to 6 quarts per minute. There also was a corresponding decline in the evening readings until September 23, by which time the evening discharge of the little stream had ceased. It did not resume until the evening of October 3, or three days after the abrupt and continued drop in temperature. The evening readings showed an increasing discharge until October 9, when again there was an apparent response to rising temperature. This response was not, however, apparent in the morning readings until the morning of October 10. Although it was impossible to control any of the several possible variables, it seems probable that the rate of discharge by the end of the day was influenced by temperature and sunshine. This relationship is indicated by the stream's evening performance from October 2 to 12, during which time the minimum rate of discharge rose from 0.0 quarts per minute on October 2 to 3.00 quarts per minute on October 8 and then declined through 2.40, 1.76, and 1.20 to 1.10 quarts per minute on October 12. The maximum evening discharge, namely, 3.00 quarts per minute, occurred on the 8th. On that day there was a total of but 23 per cent of sunshine. On the following day there was a total of 29 per cent. Thereafter, the per centage of sunshine rose to 77 per cent on the 10th and to 100 per cent on the 11th and 12th.

TABLE 1.—*Daily maximum and minimum rate of water discharge of stream at Bryn o Dderw, Cabin John, Md., for the 28-day period, September 15 to October 12, 1930*

[The temperature, relative-humidity, and sunshine data were recorded by the Weather Bureau at Washington, D. C.]

| Day | Quarts per minute | | Temperature | | Relative humidity | | | Sunshine |
|---|---|---|---|---|---|---|---|---|
| | 7.00 a. m. | 6.15 p. m. | Maximum | Minimum | 8 a. m. | Noon | 8 p. m. | |
| | | | | | *Per cent* | *Per cent* | *Per cent* | *Per cent* |
| Sept. 15 | 6.00 | 1.30 | 97 | 71 | 93 | 52 | 53 | 84 |
| Sept. 16 | 5.00 | (1) | 95 | 72 | 73 | 49 | 87 | 69 |
| Sept. 17 | 7.50 | 3.40 | 88 | 70 | 81 | 43 | 41 | 78 |
| Sept. 18 | 5.20 | 2.40 | 78 | 61 | 53 | 32 | 58 | 63 |
| Sept. 19 | 5.00 | 1.90 | 82 | 59 | 71 | 32 | 61 | 50 |
| Sept. 20 | 5.00 | 1.50 | 84 | 61 | 83 | 47 | 58 | 72 |
| Sept. 21 | 5.00 | 1.05 | 88 | 68 | 87 | 43 | 60 | 64 |
| Sept. 22 | 5.00 | 0.0 | 93 | 66 | 67 | 37 | 46 | 89 |
| Sept. 23 | 5.00 | 0.0 | 90 | 70 | 65 | 37 | 48 | 79 |
| Sept. 24 | 4.80 | 0.0 | 92 | 66 | 80 | 61 | 71 | 67 |
| Sept. 25 | 4.78 | 0.0 | 95 | 72 | 80 | 45 | 64 | 59 |
| Sept. 26 | 4.78 | 0.0 | 96 | 70 | 77 | 44 | 51 | 100 |
| Sept. 27 | 4.75 | 0.0 | 81 | 58 | 44 | 24 | 31 | 78 |
| Sept. 28 | 4.78 | 0.0 | 81 | 52 | 70 | 28 | 43 | 100 |
| Sept. 29 | 4.60 | 0.0 | 75 | 53 | 50 | 26 | 38 | 76 |
| Sept. 30 | 4.40 | 0.0 | 71 | 52 | 56 | 38 | 38 | 88 |
| Oct. 1 | 5.40 | 0.0 | 64 | 46 | 70 | 40 | 49 | 93 |
| Oct. 2 | 5.40 | 0.0 | 68 | 45 | 66 | 36 | 53 | 100 |
| Oct. 3 | 5.45 | 1.30 | 69 | 44 | 69 | 40 | 54 | 79 |
| Oct. 4 | 6.00 | 1.00 | 67 | 52 | 63 | 33 | 36 | 87 |
| Oct. 5 | 5.40 | 1.50 | 67 | 43 | 54 | 32 | 34 | 85 |
| Oct. 6 | 5.40 | 1.80 | 75 | 42 | 71 | 33 | 55 | 97 |
| Oct. 7 | 5.70 | 1.80 | 78 | 44 | 80 | 31 | 46 | 83 |
| Oct. 8 | 5.70 | 3.00 | 70 | 58 | 84 | 50 | 59 | 23 |
| Oct. 9 | 5.70 | 2.40 | 72 | 59 | 84 | 61 | 69 | 29 |
| Oct. 10 | 5.70 | 1.76 | 78 | 55 | 91 | 57 | 72 | 77 |
| Oct. 11 | 5.40 | 1.20 | 77 | 54 | 81 | 47 | 61 | 100 |
| Oct. 12 | 5.00 | 1.10 | 77 | 53 | 87 | 47 | 60 | 100 |

[1] Rain, 0.33 inch.

[1] Bates, C. G., and A. J. Henry. Forest and stream-flow experiment at Wagon Wheel Gap, Colo. MONTHLY WEATHER REVIEW, Suppl. No. 30, U. S. Dept. Agr. Weather Bureau. 1928.

[2] Transpiration affects stream flow. Engineering News-Record, Vol. 105, No. 17, p. 662. Oct. 23, 1930.

The temperature for the period October 6 to 12 remained relatively uniformly high; and the fact that there was this sudden increase in discharge at the end of the day would seem to indicate an important relationship between sunlight and stream discharge, at least so in this particular instance.

There is no apparent correspondence between mean relative humidity from day to day and daily fluctuations in the rate of discharge of the little stream under observation, though it is conceivable that differences in this variable must have had their parallel differences in the loss of water from the leaf surface of the trees and other vegetation through evaporation.

Until the 1st of October the 32 trees and other vegetation in the ravine under observation were functionally very active, and their diurnal water requirement was consequently high, perhaps approximating the maximum, highest from sun to sun and sinking to a minimum during the night. To determine the total daily discharge of our little stream and, inversely, the approximate daily water consumption of the plants dependent on this source of supply, hourly readings were made from 7 p. m., September 27, to 7 a. m. September 29. (Table 2.) It will be seen that the trees and undergrowth exerted an ever-increasing "pull" on the supply from about 10 a. m. until late afternoon and that no water was running from just before 3 o'clock p. m. to a little after 7 o'clock. The theoretical total discharge for the 36-hour period was 6,264 quarts. Since October 3 the stream has not ceased to flow at all hours of the day and night, and now that the vegetation has either died or entered upon its period of winter rest, the hourly rate of discharge remains virtually constant at 6 quarts per minute.

TABLE 2.—*Hourly increase and decrease in rate of discharge of reservoir inlet at Bryn o Dderw, Cabin John, Md., from 7 p. m., September 27, to 7 a. m., September 29, 1930*

| Hour | Discharge (quarts per minute) | Temperature [1] F. | Hour | Discharge (quarts per minute) | Temperature [1] |
|---|---|---|---|---|---|
| 7:00 p. m. | 0.00 | 70 | 2:00 p. m. | 0.46 | 77 |
| 8:00 p. m. | 0.90 | 69 | 3:00 p. m. | 0.00 | 80 |
| 9:00 p. m. | 1.20 | 66 | 4:00 p. m. | 0.00 | 80 |
| 10:00 p. m. | 2.49 | 62 | 5:00 p. m. | 0.00 | 79 |
| 11:00 p. m. | 3.00 | 60 | 6:00 p. m. | 0.00 | 76 |
| 12:00 m. | 3.33 | 58 | 7:00 p. m. | 0.00 | 72 |
| 1:00 a. m. | 3.75 | 57 | 8:00 p. m. | 1.05 | 71 |
| 2:00 a. m. | 3.94 | 55 | 9:00 p. m. | 2.00 | 71 |
| 3:00 a. m. | 4.13 | 54 | 10:00 p. m. | 3.00 | 68 |
| 4:00 a. m. | 4.32 | 53 | 11:00 p. m. | 3.10 | 64 |
| 5:00 a. m. | 4.51 | 52 | 12:00 m. | 3.38 | 63 |
| 6:00 a. m. | 4.70 | 52 | 1:00 a. m. | 3.66 | 60 |
| 7:00 a. m. | 4.78 | 52 | 2.00 a. m. | 3.94 | 56 |
| 8:00 a. m. | 4.78 | 58 | 3:00 a. m. | 4.22 | 58 |
| 9:00 a. m. | 4.78 | 66 | 4:00 a. m. | 4.50 | 56 |
| 10:00 a. m. | 4.28 | 72 | 5:00 a. m. | 4.60 | 54 |
| 11:00 a. m. | 3.24 | 74 | 6:00 a. m. | 4.60 | 54 |
| 12:00 n. | 2.20 | 75 | 7:00 a. m. | 4.60 | 53 |
| 1:00 p. m. | 1.15 | 77 | | | |

[1] Washington, D. C., temperature at Weather Bureau Observatory Twenty-fourth and M Streets NW.

Total discharge, 6,264 quarts.
Total 24-hour discharge 8,352 pounds.
Total possible 24-hour discharge, 13,766 pounds.
Total taken by vegetation, 5,414 pounds.

According to Table 2, the maximum rate of discharge obtained between 7 and 9 o'clock a. m. But, since after leaf fall and prior to any possible augmentation from rainfall, the discharge increased to the rate of 6 quarts per minute, the difference between this maximum and that recorded on the 28th of September, i. e., 1.22 quarts per minute, may be assumed to represent approximately the index to the minimum respiration requirement of the trees and undergrowth. We may therefore safely assume that had there been no vegetation tributary to this water supply the rate of discharge during the 36-hour period recorded in Table 2 would have been approximately 6 quarts per minute. The total discharge would then have amounted to 12,960 quarts. The difference, 6,696, between 12,960 and 6,264, the recorded total discharge of the stream during the 36-hour period, should therefore roughly represent the number of quarts of the water consumed by the vegetation. This, converted to weight units, becomes 13,392 pounds, or 6.7 tons.

At present writing, November 20, the precipitation at Washington since November 1 has been exactly 0.50 inch. That for Cabin John has been even less. It is therefore probable that very little, if any, water has been added to the daily discharge of the little stream here under consideration. It is now discharging at the almost hourly constant rate of 6 quarts per minute, or 360 quarts per hour, or at the same rate recorded on November 1. It should here be observed also that with the advent of the cool October days and cooler November, together with the almost complete cessation of all plant growth demands on the soil moisture, the level of Cabin John Run at Aqueduct Bridge is now between 6 and 7 inches higher than it was 60 days ago.—*Harry B. Humphrey.*

### STREAM-FLOW RETURNS BEFORE THE RAINS COME [1]

"The return of the flow of water in the streams of Fairfax County, Va. (near Washington, D. C.), before the occurrence of rain became noticeable with the coloring of the leaves in early October, and was well marked after the time of killing frosts, October 21, 22, and 23. The upper portion of Pimmett Run, a branch of the Potomac, ceased to flow as a continuous stream August 9, although there were pools here and there fed by springs. No one can establish that it ever ceased to run before. Its flow began again toward the end of October. Small springs here and there kept a continuous discharge throughout the entire period, but the water made but little progress down the course of the stream. The only water in Burke Spring Run, a branch of Pimmett Run, came from a spring at the base of a hill used for farming purposes. This spring appears to have dwindled slightly throughout the period but was still active October 26. These streams are in a farm-land community, but trees and bushes grow close to them for the greater length of their course." The Fairfax Herald of November 7, 1930, carries the following:

In spite of the fact there have been no rains to bring water back into streams in the county, it is reported that a considerable trickle of water has reappeared in Difficult Run, and W. E. Kirby, residing about 2 miles north of Falls Church, states that water has returned to what is known as Burke Spring Run, that empties into Pimmett Run. For several weeks past Mr. Kirby has been watering his cows by carrying water to them from his pump, which has not failed him, but now he is able to water the cows at the run, much to his delight. Reports coming from the south side of the county, in the vicinity of Accotink, say that water has reappeared in streams in the vicinity of Camp Humphreys. J. L. Millan, residing on Chain Bridge Road, a short distance beyond Wiley station, reports that a spring on his place that has been dry for several weeks came to life a few days ago, and a good stream of water is flowing from it down to the bed of a small creek, which it fed.

The Herald would like to hear from other sections of the county if water is reappearing in streams and springs.

—*B. C. Kadel.*

[1] The following note by Mr. Kadel shows that the phenomenon described by Doctor Humphrey was more or less general in Virginia just across the Potomac River from Cabin John, Md.—*Ed.*

### THE PRECIPITATION IN CANADA

*January.*—The month was quite dry from the Pacific coast to the head of the Great Lakes, and also through northern Ontario into northern Quebec. In parts of southern Ontario the snowfall was unusually heavy and the same condition prevailed largely in western Quebec. In Prince Edward Island and part of southern Nova Scotia precipitation was considerably in excess while in New Brunswick it was generally less than normal.

*February.*—Precipitation was deficient in Alberta, southern Saskatchewan, southern and eastern Ontario, the St. Lawrence Valley and the Gulf regions, and parts of the Atlantic Provinces. There was an excess in British Columbia, the central portion of the grain belt in Saskatchewan, in Manitoba, northwestern Ontario, southern New Brunswick, Prince Edward Island, and a part of Nova Scotia, also in the far northern regions for the most part as yet unknown.

*March.*—Precipitation was considerably above the normal amount in the Yukon and the lower Mackenzie Valley, in parts of northern Ontario, along the lower St. Lawrence Valley and part of the Gulf region, and in parts of the Atlantic Provinces. There was a moderate excess in the counties north of Lake Erie and Ontario and in western and northern Manitoba, part of northeastern Saskatchewan, locally in Alberta, and locally in the interior of British Columbia.

There was a moderate deficiency in western and southwestern British Columbia except locally. There was a moderate deficiency in Alberta and Saskatchewan, as a whole, but a fairly large deficiency in northern Alberta and the extreme southern portions of both Alberta and Saskatchewan. A moderate deficiency occurred in the eastern portions of the Atlantic Provinces.

*April.*—Over most of Canada this was a dry April. In Ontario, Quebec, except the lower St. Lawrence Valley, the Atlantic Provinces, Manitoba, except the Dauphin district, eastern and northern Saskatchewan, part of northern Alberta, and in parts of British Columbia, precipitation was less than normal by 25 to 50 per cent for the most part.

In southern Alberta and southwestern Saskatchewan the month was much wetter than usual, two to four times the usual amount being recorded over a large area. In British Columbia excesses of 40 to 50 per cent of the normal amount were recorded in some places and deficiencies of 10 to 50 per cent in others. In the lower St. Lawrence Valley excesses were 10 to 50 per cent of the normal amount.

*May.*—During May precipitation over the Dominion occurred for the most part as passing showers with great variation in intensity in short distances. In most of Manitoba and part of eastern Saskatchewan the excess over the normal amount ranged from 40 to 180 per cent. In southwestern Quebec the excess ranged from 5 to 125 per cent. In Ontario there were some moderate deficiencies and some large excesses with a moderate excess generally. In the Atlantic Provinces and the Gulf region of Quebec, totals were generally below normal although northeastern Nova Scotia and a few other localities had an excess. In the Peace River country and part of the Edmonton region precipitation was either normal or considerably in excess.

*June.*—The remarkable feature of the month was the unprecedented rainfall in northern Ontario and northern Quebec. From 10 to 15 inches were reported from the vicinity of Lake Temiskaming and Lac des Quinze. Several times during the last 10 years there have been very wet months in northern Ontario with totals of 5 to 8 inches, but the previous highest total was 8½ inches, while the average rainfall for June during the last 35 years is a little in excess of 2¾ inches. * * * In southern Ontario the rainfall was about twice the normal amount in some localities while there were deficiencies in the region of Lake St. Clair and locally on the shore of Ontario.

Rainfall was deficient in Alberta by 10 to 40 per cent except in the Lloydminster-Vegreville area and the Peace River Valley where there was an excess. In Saskatchewan considerable areas in the north and south portions of the grain zone had excesses of about 35 per cent, while the central part of the zone had deficiencies of 10 to 50 per cent. In Manitoba rainfall was well above the normal in the central districts and moderately deficient elsewhere. In the Atlantic Provinces the month was very dry in Nova Scotia, Prince Edward Island, and parts of southern New Brunswick, while the northern New Brunswick there was an excess, with exceptionally heavy rain in some districts. In British Columbia the southern interior and Vancouver Island were considerably drier than usual while in the northern interior and on the northern coast the month was moderately wet.

*July.*—On the southern margin of the northeast cool front, frequent rainfalls occurred during July, totalling 4 to 8 inches in the wettest districts of northern Ontario and Quebec and parts of the Atlantic Provinces. The occasional excursions of cool air into the northwest were followed by good rains in parts of Manitoba, and northern sections of the wheat region of Alberta and Saskatchewan totalling 2 to 6 inches. In the far northwest and northeast two to three times the usual rainfall occurred. In the southern portions of the grain region, southwestern Ontario, and in British Columbia, except the north Pacific coast, very little rain fell.

*August.*—The month was generally drier than usual from the Pacific Ocean eastward to the Ottawa River. Over a large part of this area the deficiency was very great. In the Lake St. John and Saguenay region of Quebec, the Gaspe Peninsula and generally in New Brunswick except the extreme south, August was a month of frequent rains with the total rainfall exceeding the normal amount. In the Temiskaming region of northern Ontario rain was also heavy. In Nova Scotia there was generally a moderate deficiency.

*September.*—Less than the usual amount of precipitation was recorded in the Yukon and far northern British Columbia, but in the middle latitudes of British Columbia from Prince Rupert to the upper Fraser Valley and thence east to Yellowhead Pass and the Peace River Valley there was an excess over the normal amount of about 30 per cent in the interior and about 10 per cent on the coast.

In southern British Columbia, as well as in that part of Alberta lying between Edmonton and Calgary, precipitation was generally less than normal. In extreme southern Alberta, and in Saskatchewan, except the southeast, there was an excess of approximately 25 per cent, with locally quite heavy amounts in the Prince Albert-Saskatoon region. In southeastern Saskatchewan, southern Manitoba, southern Ontario, southwestern Quebec, and the greater part of the Atlantic Provinces, as well as the Abitibi slope and the Lake of the Woods region in northern Quebec, the total was less than normal. In southeastern Saskatchewan, southern Manitoba, and the Lake of the Woods region the deficiency was generally from one-third to one-half of the normal amount. In southern Ontario the deficiency varied from 10 to 60 per cent. In the Atlantic Provinces rainfall was generally from 20 to 90 per cent below the normal. In southern Quebec the deficiency was 20 to 60 per cent. Along the north shore of Lake Superior to Sudbury and Haileybury and also in the region of Lake St. John and locally in the upper valley of the St. Maurice as well as in the Gaspe Peninsula and parts of the north shore of the Gulf of St. Lawrence, showers were frequent with moderate excess over the normal. Norman, Smith, and Churchill, in the far north, reported excesses of 30 to 90 per cent of the normal, while Simpson, Aklavik, and Chesterfield reported deficiencies. Returns from the Coppermine were incomplete.

*October.*—Precipitation was generally well above normal from Lake Superior to the Pacific Ocean, except in the far northwest. From Lake Superior and the Abitibi River south and east to the Bay of Fundy, precipitation was generally deficient. In Nova Scotia there was an excess over the normal amount except immediately along the coasts of the Bay of Fundy.—(*Excerpted from the Monthly Weather Map of Canada for the several months, January to October, 1930.*)

From the foregoing it is evident that Canada, especially in June and July, was favored with a greater rainfall about the Hudson Bay region and parts of northern Ontario and northern Quebec, than was received below the border between Canada and the United States.

Daily pressure charts for the Northern Hemisphere make it clear why the precipitation in Canada was less scant than in the United States. During the first half of July, for example, several rather extensive areas of high pressure occupied the North Atlantic not far to the eastward of the Canadian Maritime Provinces; these

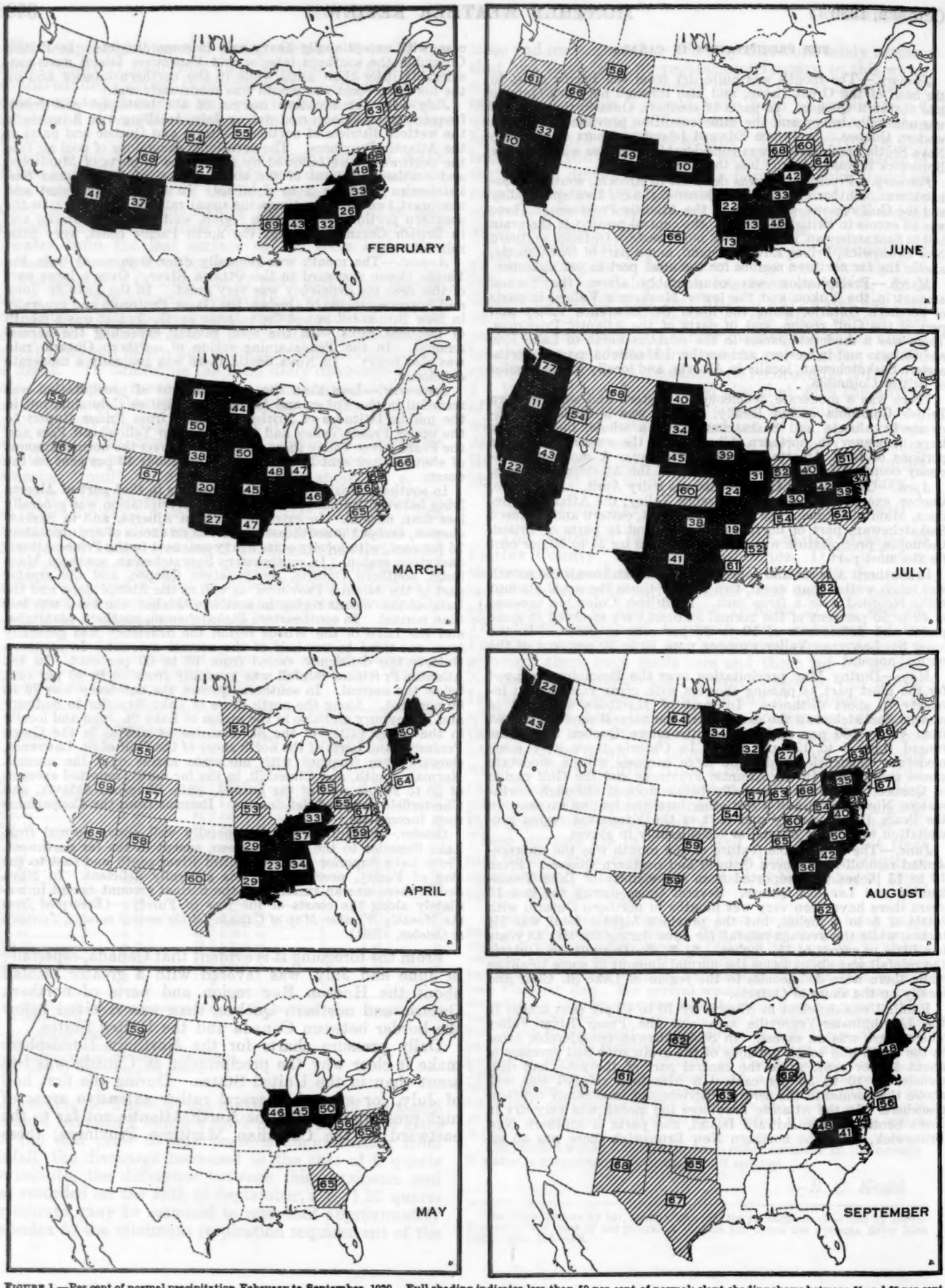


FIGURE 1.—Per cent of normal precipitation February to September, 1930. Full shading indicates less than 50 per cent of normal; slant shading shows between 51 and 69 per cent of normal or a near drought

formations doubtless were responsible for the abnormal course of cyclonic systems that otherwise would have moved in a more nearly normal direction; during the second half of the month the areas of high pressure over the western North Atlantic were found farther south with westward extensions over the continent of North America and as previously stated they were a distinct deterrent to precipitation over eastern United States. On July 31 an unbroken area of high pressure extended from the Spanish coast on the east across the Atlantic and the Continent and still farther west over the Pacific at least to the one hundred and seventieth meridian of west longitude, while the only low pressure on that date was along or near the Arctic Circle in both Europe and America and northeastern Asia. The full story of the drought will not be told until definitive data for the Northern Hemisphere are available. The course of the drought in the United States from month to month is portrayed graphically by the series of 9 small charts of Figure 1.—*A. J. Henry.*

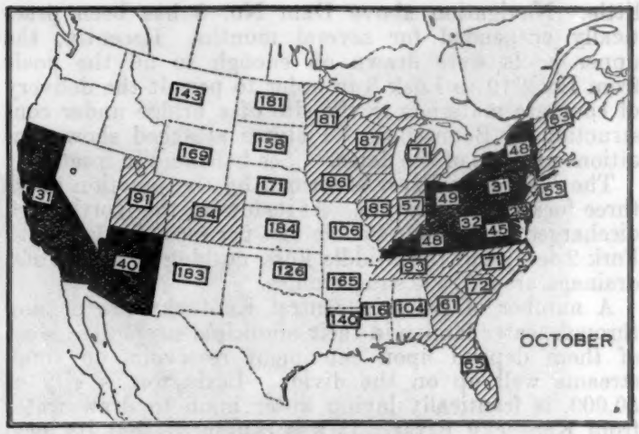


FIGURE 1A.—Per cent of normal precipitation. This chart shows the per cent of normal in all States from which reports have been received. Texas, Washington, Oregon, Nevada, and Idaho not yet available

## DROUGHT IN OHIO VALLEY AND WATER SUPPLY

By W. C. DEVEREAUX

[United States Weather Bureau, Cincinnati, Ohio]

The general drought of 1930 in the Ohio Valley began in March or April, and continues at the end of November. The surface run-off practically stopped early in the summer, and the underground water supply diminished rapidly and by the middle of the summer the springs ceased flowing, the creeks and small rivers dried up, and wells failed. These conditions became more acute during August. In September there were fairly good rains over most sections of the valley which revived pastures and restored growing conditions, but there was no run-off to start stream flow or affect the municipal water supply.

The months of October and November (to the 25th) were the driest of the year, thus far, at Cincinnati and probably in most of the Ohio Valley. From 58 stations well distributed over the Ohio Valley and reporting daily to Cincinnati, the average rainfall for October was 1.30 inches and for November 1 to 25 it was 1.37 inches. These amounts are less than one-half of the normal amounts in both months for the area which includes Kentucky, Tennessee, West Virginia, the middle and southern portions of Indiana and Ohio, and extreme western Pennsylvania.

Not only the smaller rivers have been dry all summer, but many of the larger rivers are now dry where artificial pools have not been maintained. In the Kentucky River above Beattyville where the last dam is located there is only a "trickle" of water coming over the bed of the river. This river drains 1,654 square miles and is fed by mountain streams. The United States Engineers find the stream flow to be between 2 and 3 second-feet, estimated as it is impossible to measure it. The same is true of many other rivers in the Ohio Valley.

The municipal water supply has given out in practically all the cities and towns where the water was obtained from unimproved rivers, wells, or springs. At Lexington, Ky., water has been drawn by trainloads for several weeks from the pools in the Kentucky River. At present the construction of a pipe line to the river, a distance of about 25 miles, is being pushed so as to have service in the same by December 1. Even cities like Vanceburg on the Ohio River, but which have depended on wells for their water supply, are now constructing water-supply systems.

Fortunately the Federal Government had completed the 50 dams in the Ohio River before the great drought of 1930. These dams have maintained full pools from Pittsburgh, Pa., to Cairo, Ill., during the entire summer and fall. These dams have formed a series of 50 lakes averaging 10 or more feet deep, from 1,400 to 3,000 feet wide, and extending a distance of 1,000 miles. Many of the larger tributaries such as the Allegheny, Monongahela, Muskingum, Kanawha, Kentucky, etc., have been improved by dams. The water from the pools in these rivers has made it possible for life to exist and business to progress in the Ohio Valley during the driest season of record in the valley.

Principal Hydroelectric Engineer W. S. Winn, of the United States Engineer office, Cincinnati, Ohio, supplies some of the details of low water in Kentucky River and the illustrations presented in the note next below.

## LOW WATER IN THE KENTUCKY RIVER, 1930

By W. S. WINN, Principal Hydroelectric Engineer, United States Engineer Office, Cincinnati, Ohio

A statement of low-water conditions on Kentucky River during the current season follows:

I think there is little doubt that the drought of this year has been the worst on record. Early in the summer old citizens of central Kentucky began comparing it with the drought of 1855. For the three months, July to September, inclusive, the rainfall was only 3.23 inches, being 7.27 inches below normal. October and November rainfall was below normal, but data are not yet available.

The effect on navigation has been to lower pools below crests of dams. The pool above Dam No. 8 fell 4 feet below crest of dam. All of the pools above Dam No. 8 have dropped more or less below dam crests. Below Dam No. 8 the pools have been kept full by leakage and operating water discharged from Dix River Dam. However, for the past several months, most of the water from Dix Dam has been leakage since the reservoir had been drawn down 50 feet below normal and the Dix River power plant has been operated very

little. Navigation above Dam No. 8 has been practically suspended for several months. Recently, the upper pools were drawn off enough to fill the pools from Lock 10 to Lock 8 in order to permit the delivery of concrete materials to the site of a bridge under construction at Boonesboro. Pictures attached show conditions at some of the dams. (See halftones in inset.)

The Kentucky River is formed by the junction of its three forks at Beattyville. At its lowest, the North Fork discharged only about 4 cubic feet per second; the South Fork 2 feet; and the Middle Fork nothing at all. Total drainage area, 2, 500 square miles.

A number of cities in central Kentucky are passing through water famine in their municipal supplies. Most of them depend upon catchment reservoirs on small streams well up on the divide. Lexington, a city of 50,000, is frantically laying water main to draw water from Kentucky River. It was estimated that its local supply would be exhausted about December 1, and that Kentucky River water would be pumped into the reservoirs November 26. Shelbyville has been hauling water by train from Louisville for several months. Paris was rationed to two hours a day until a citizen who had a private reservoir upstream, drained his reservoir into the municipal supply. Richmond was asking for elevations of Kentucky River pools with a view to laying a pipe line to the river. I have not heard what became of the plan, but do know they were in dire need of water. A manufacturing plant at Lawrenceburg has been hauling water from the river in motor tanks, but has been given a permit to pump water from the river to its plant. The city of Lawrenceburg is on water ration.

Smaller towns and villages and individuals have been hauling water from the river for months. Many of the farmers were compelled to dispose of their livestock at a sacrifice for lack of stock water.

## SQUALL LINES IN NEW MEXICO

By CLEVE HALLENBECK

[Weather Bureau Office, Roswell, N. Mex.]

The "squall line" as it is observed in the eastern half of the United States is unknown in the elevated regions of the Southwest, and probably in the rest of the western highlands also. The typical squall-line barometric depression rarely forms over the mountainous West, and when it invades this region it soon disappears. This probably is due to the topography. A cold front of any considerable breadth is speedily broken up into isolated streams or so thoroughly mixed with the warmer air that it loses its identity as a cold front.

Figure 1 will give some idea of the effect of the mountain barriers upon the integrity or continuity of a southward flow of cold air. Contour intervals are shown at 5,000, 7,000, and 10,000 feet. The cold front, which over a plains region would be comparatively unbroken, is here split up into innumerable streams, moving in different directions and at different rates of speed. These streams are further divided, by minor topographic features not shown on the map. Were the general movement from the northwest instead of the north, an entirely different set of "air streams" would result, and still another if from the west. At Roswell the pioneer stream of cold air may approach through either of two broad gaps in the mountains to the west or through the still broader general depression to the northwest. Were wind directions recorded to 32 points of the compass, the directions W. 20° S., W. 10° N., and NW. would greatly preponderate in the westerly directions, each of these three directions pointing to gaps in the mountain barriers.

When the southward flow is from east of the Rocky Mountains, it constitutes an entirely different stream of air, indicating that those mountains constitute an effective barrier clear up through Colorado. It is much damper and colder than the southward flow, west of the Rockies, that is produced by the same barometric gradient. Of this we shall have more to say presently.

Whether the cold stream is shallow or deep makes little difference so far as the effect of topographic barriers is concerned. But from observations of the movements of the lower clouds, including low stratus, it appears that the *front* of the advancing cold air is quite shallow and is governed in its direction, from bottom to top, by the topography, much as an inundation of water, 100 to 1,000 meters deep, would be. Its depth gradually increases until, after 6 to 12 hours, the mountain ridges are, so to speak, submerged. That portion of the movement above the level of the mountain barriers probably is little influenced thereby, but the lower portions of the advancing cold air continue to be largely governed by the topography. These conclusions are borne out by observations of the movements of clouds. Ordinarily, the underrunning stream reaches the level of stratus clouds within 6 hours and the level of strato-cumuli within 12 hours. Sometimes, however, it does not reach the level of the strato-cumuli at all.

Each of the isolated streams shown in Figure 1 may produce thunderstorms, and usually does so when there has been an importation of relatively moist air into the region. As a rule, east of the Continental Divide moisture can be brought in only from the Gulf of Mexico, while over most of Arizona it can come only from the Pacific Ocean. In the highlands embracing western New Mexico and extreme eastern Arizona, moisture may be imported from either direction.

A peculiar squall condition usually is observed in eastern New Mexico in connection with a pressure system similar to that shown in Figure 2. This is the movement of a stream of relatively cold air—apparently a straying portion of the counterflow west of the barometric trough—moving from the Northwest, as shown in the chart. It produces thunderstorms over the low plateaus between the Colorado-San Juan Valleys and the Grande Valley, and also between the valleys of the Grande and the Pecos. These two plateau regions are highlands as compared with the river valleys, but lowlands as compared with the mountain walls on each side. Such storms occur when the pressure distribution is approximately as shown on the chart; in fact, this chart is a composite of 18 pressure systems of the type illustrated, each of which produced thunderstorms on the uplands between the Pecos and Grande Valleys. These storms often form along a general front 50 to 150 miles wide, and usually deliver copious precipitation at elevations of 6,000 to 7,000 feet. Hail and violent winds may accompany them. The underrunning current from the Northwest may persist 6 to 12 hours, and is not a transient wind belonging wholly to the thunderstorm circulation.

Thereafter there is a return to fair weather unless the pressure distribution remains practically unchanged. Normally, the northern center of depression moves

UNIV. OF MICH.

*Upper.*—North Fork Kentucky River below Beattyville. Discharge, about 4 cubic feet per second
*Lower.*—Middle Fork Kentucky River at Beattyville. Discharge, zero

(To face p. 403)

Kentucky River above Beattyville; drainage area, 1,654 square miles. Discharge, 22 cubic feet per second

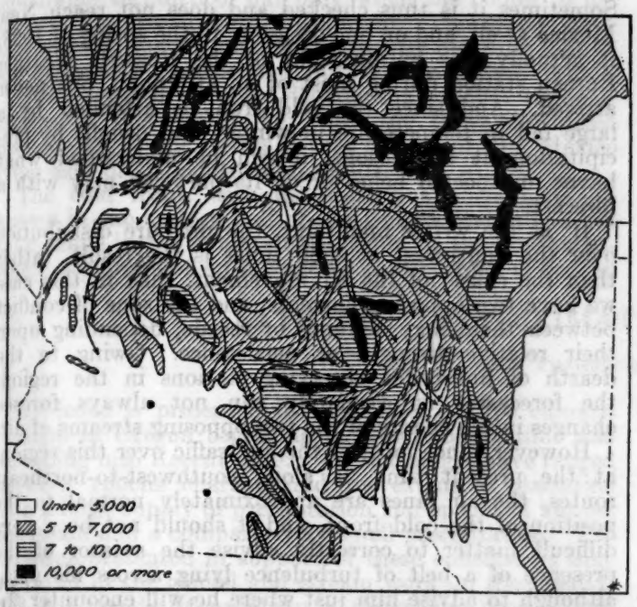


FIGURE 1.—Influence of mountain topography of New Mexico in breaking up and deflecting an advancing stream of relatively cold and dense air. Solid black, elevation of land 10,000 feet or higher; horizontally shaded, 7,000 to 10,000 feet; vertical shading, 5,000 to 7,000; unshaded, below 5,000 feet

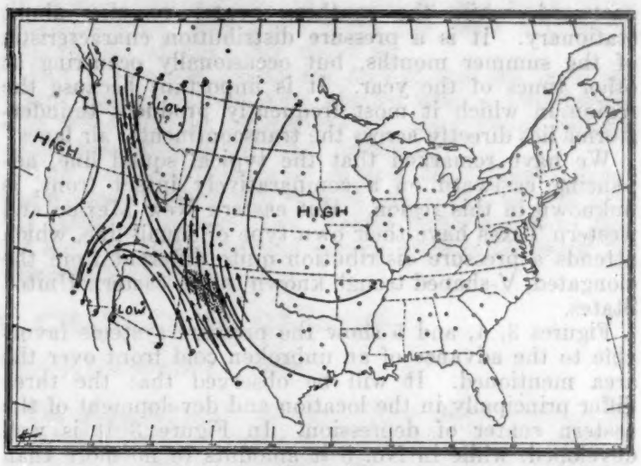


FIGURE 2

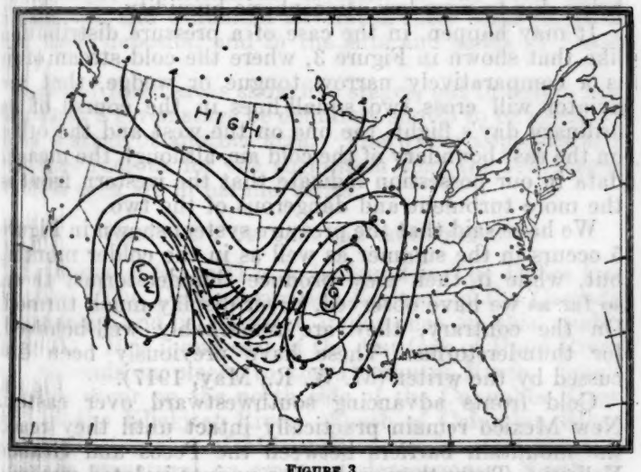


FIGURE 3

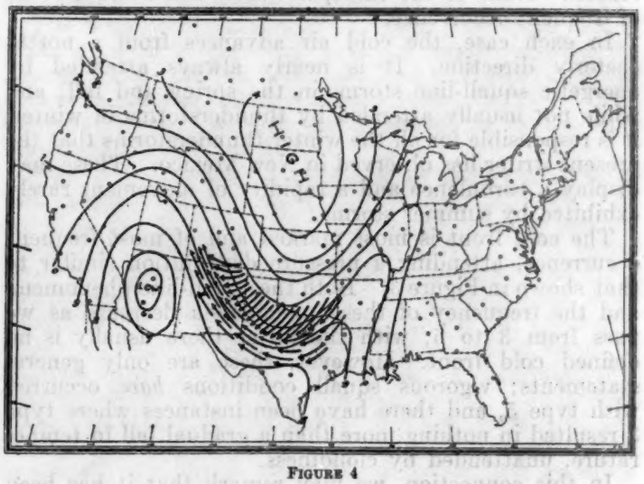


FIGURE 4

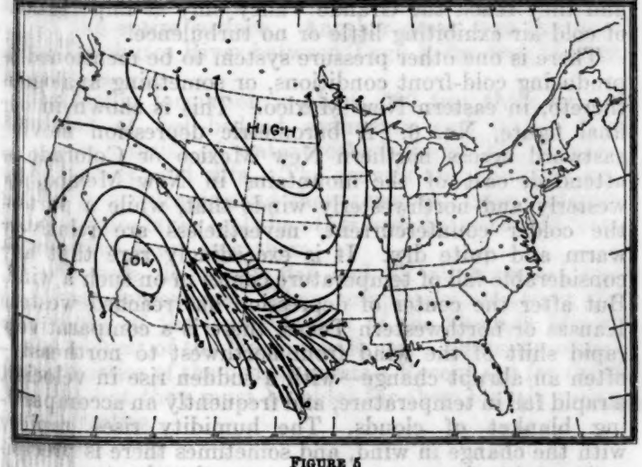


FIGURE 5

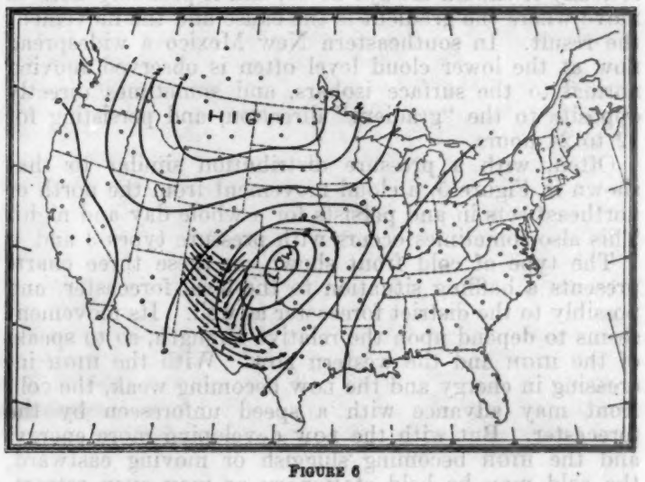


FIGURE 6

Figures 2-6.—Idealized charts of pressure and wind distribution

eastward, while the southern center remains about stationary. It is a pressure distribution characteristic of the summer months, but occasionally occurring at other times of the year. It is important because the region in which it most frequently produces thunderstorms lies directly across the transcontinental air lanes.

We have remarked that the typical squall line, advancing eastward on a comparatively intact front, is unknown in this region. But eastern New Mexico and western Texas have their own type of squall line, which attends a pressure distribution quite different from the elongated, V-shaped trough known to the eastern United States.

Figures 3, 4, and 5 show the pressure systems favorable to the advance of an unbroken cold front over the area mentioned. It will be observed that the three differ principally in the location and development of the eastern center of depression. In Figure 3 it is well developed, while in No. 5 it amounts to no more than a southeastward elongation of the western depression. Nos. 3 and 4 are characteristic of the colder half of the year. No. 5, while it may occur summer or winter, is perhaps more frequent in the latter than in the former season. None of the three, however, can be said to be of frequent occurrence.

In each case, the cold air advances from a northeasterly direction. It is nearly always attended by energetic squall-line storms in the spring and fall; and while not usually attended by thunderstorms in winter, it is responsible for all the winter thunderstorms that the present writer has observed in New Mexico. These may display a turbulence and a rapidity of movement rarely exhibited by summer storms.

The cold front is most marked and of most frequent occurrence, attending a pressure distribution similar to that shown in Figure 3. Both the squall-line phenomena and the frequency of these phenomena decrease as we pass from 3 to 5; with the latter there usually is no defined cold front. However, these are only general statements; vigorous squall conditions *have* occurred with type 5, and there have been instances where type 3 resulted in nothing more than a gradual fall in temperature, unattended by cloudiness.

In this connection, we may remark that it has been our observation that the air at the lower cloud level moves approximately parallel to the surface isobars—when it does not move in some other direction. Theoretically it should always do so, and it probably does so move where the gradient is the cause and the movement the result. In southeastern New Mexico a widespread flow at the lower cloud level often is observed moving normal to the surface isobars, and sometimes directly opposite to the "gradient" direction, and persisting for 12 to 24 hours.

Often, with a pressure distribution similar to that shown in Figure 5, a cloud movement from the north or northeast sets in and persists for a whole day and night. This also sometimes occurs with pressure types 3 and 4.

The type of cold front shown on these three charts presents a baffling situation to the local forecaster, and possibly to the district forecaster as well. Its movement seems to depend upon the relative strength, so to speak, of the HIGH and the western LOW. With the HIGH increasing in energy and the LOW becoming weak, the cold front may advance with a speed unforeseen by the forecaster. But with the LOW developing more energy, and the HIGH becoming sluggish or moving eastward, the cold may be held stationary or may even retreat. Sometimes it is thus checked and does not reach New Mexico at all, and on one occasion, in the spring of 1923, it actually was within sight of the Roswell Weather Bureau station during most of an afternoon, but never arrived. And since the cold front is attended by a large fall in temperature in winter, and usually by precipitation at all seasons, it can be understood what havoc unexpected behavior on its part can play with a forecast.

If as the writer maintains, the pressure distribution over the Southwest at such times is the result, rather than the cause, of the air movement, then in this case we have two opposing currents, and the zone of conflict between them may advance or recede, depending upon their relative strength or persistence. Owing to the dearth of first-order observing stations in the region, the forecaster unfortunately can not always foresee changes in the energy of the two opposing streams of air.

However, since most of the air traffic over this region, at the present time, is along southwest-to-northeast routes, the air lanes are approximately normal to the position of the cold front, and it should not be a very difficult matter to correctly advise the aviator of the presence of a belt of turbulence lying across his path, although to advise him just where he will encounter the dangerous weather is a different matter. The cold front usually is attended by much turbulence, even when there is little or no cloudiness, the absence of cloudiness being due to very low atmospheric humidity.

It may happen, in the case of a pressure distribution like that shown in Figure 3, where the cold stream of air is a comparatively narrow tongue or wedge, that the aviator will cross two squall lines in the course of an ordinary day's flight, the one on the west and the other on the east boundary of the cold air, although the meager data in our possession indicate that the western front is the more turbulent and dangerous of the two.

We have said that the pressure system shown in Figure 5 occurs in the summer as well as in the colder months, but, while it then may produce thunderstorms, these, so far as we have observed, never display much turmoil. On the contrary, they are remarkably well-behaved, for thunderstorms. These have previously been discussed by the writer (M. W. R., May, 1917).

Cold fronts advancing southwestward over eastern New Mexico remain practically intact until they reach the mountain barriers between the Pecos and Grande Valleys. There they are broken up into isolated streams, and they reach the Grande Valley only as importations of cold air exhibiting little or no turbulence.

There is one other pressure system to be mentioned as producing cold-front conditions, or something analogous thereto, in eastern New Mexico. This is shown in our final figure, No. 6. A barometric depression moving eastward across northern New Mexico or Colorado is attended, east of the mountains in New Mexico, by westerly and northwesterly winds that, while a part of the colder countercurrent, nevertheless are relatively warm and quite dry. It is exceedingly rare that any considerable fall of temperature comes in on such a wind. But after the center of depression has reached western Kansas or northwestern Texas, there is a comparatively rapid shift of the wind from northwest to northeast—often an abrupt change—with a sudden rise in velocity, a rapid fall in temperature, and frequently an accompanying blanket of clouds. The humidity rises rapidly with the change in wind, and sometimes there is precipitation. At times, too, there are thunderstorms and

squall-line turbulence, but only when the center of depression has passed south of Colorado. This type of pressure distribution occurs more frequently in spring than in any other season of the year, but no season is free from it.

Other types of pressure distribution produce thunderstorms in this region, but only the types illustrated produce squall-line storms in that portion of New Mexico lying east of the continental divide.

The cold front, with its squall-line phenomena, as known in the eastern half of the United States, can not take shape in the mountainous region of the Southwest, where the front of an advancing cold current is broken up by mountain barriers into isolated streams that produce thunderstorms, only when there has been a previous importation of relatively moist air.

But a vigorous southward flow of cold air over the plains States reaches New Mexico with a well-defined cold front moving southwestward, along which decided squall-line phenomena often occurs.

The mountain ranges of central New Mexico mark the western limit of this type of squall line, so that over the larger portion of New Mexico importations of cold air are only in the form of narrow streams following the topographic depressions.

## LATE TERTIARY CLIMATIC CHANGES IN OREGON

By EDWIN T. HODGE, Professor of Geology [University of Oregon]

Evidence is presented in this paper of five climatic changes in Oregon beginning in late Pliocene time and extending into Recent time. These changes have ranged between epochs characterized by extensive glaciation with a large supply of precipitation and epochs of limited glaciation and a comparatively small precipitation. The evidence presented in support of these conclusions may be found in the glacial and stream work on the uplands of the Cascade Mountains; in the valley profiles and deposits of streams on the west side of the Cascade Mountains and Willamette Valley; in coastal deposits; in widespread formations adjacent to the John Day, Deschutes, and Columbia Rivers; in these same canyons and their deposits; and in the silts and sands of Fossil Lake.

Each of these areas show five stages, but in only a few cases can a given stage be definitely shown to be identical with a stage of another area. The writer approves and presents reasons for the suggestion that the few stages of each area are in parallel series.

### EAST SIDE OF CASCADE MOUNTAINS

Evidence of Stage II is to be found in The Dalles formation. The Dalles formation lies east of the Cascade Mountains and is of great importance in this study. (Fig. 1.) It is found east of the east fork of Hood River and extends in places to the Deschutes River. Small patches occur on the north side of the Columbia River east of the Klickitat River. South of Columbia River and beginning east of Mosier it occurs in great tongues lying in structural or erosional depressions. North of Fifteen Mile Creek and west of Deschutes River it almost covers the entire surface. Another great area lies west of the Deschutes River between Tygh Ridge and Mutton Mountains.

The Dalles formation is about 600 feet thick and is composed of well-bedded sediments and lavas. The sediments consist of water-worked glacial till, pumice, sand, gravels, and silts. The gravels and bowlders embedded in a volcanic sand show torrential cross-bedding. The andesitic lavas seal the other beds between and form a protective cover over them.

These beds lie nearly flat and fill all erosional and structural depressions. They completely obliterate the topography of the lowlands east of the Cascade Mountains and west of the Deschutes River. These structural characteristics of the beds suggests a Recent age for these deposits, but they must be older for they contain many glacial erratics.

For instance, near the city of The Dalles subangular, striated glacial erratics are abundant. They range in size from 15 feet in diameter to several inches in diameter. Associated with these are many subangular fragments which show no striation or polishing, but strongly suggest glacial origin. Some of these occur in a gray fluffy silt, wherein they have a most heterogeneous arrangement and look like true glacial deposits.

The larger fragments in The Dalles formation, which make up over 50 per cent of it, are clearly referable to Mount Hood. Furthermore, the materials can be traced almost to Mount Hood but not the entire distance. The interruption that defeats the complete tie is the east branch of Hood River Valley.

The Dalles formation, though it contains glacial erratics, is made up essentially of torrential materials. At the time this is written it is not certain whether glaciers extended as far eastward as The Dalles. It is quite likely that glaciers did reach 30 miles eastward from (say) Mount Hood, as shown by other morainal deposits mentioned below. The Dalles formation may be, therefore, either an outwash plain deposit, given off in front of glaciers on the Cascade Mountains, or aggradational deposits formed by streams active during a nonglacial stage following a glacial stage. For the purpose of the theory presented here it does not matter which origin is correct; the one essential fact is certain that an early glacial stage existed.

The glaciers that produced The Dalles formation, if they did not reach 30 miles eastward, at least extended far beyond the east fork of Hood River.

One of the most striking features regarding the Pleistocene, as of the present, is the evidence of intense glaciation on the east side of the Cascade Plateau. The presence of the glaciers at the present time is determined by the fact that the moist winds striking these mountains come from the west. During the ice age the prevailing winds were undoubtedly from the same direction, and a controlling factor in that glaciation was the superior altitude of the crest of the Cascade Mountains. The elevated crest robbed the winds of their moisture. Much of the snow falling from the chilled winds rising over the Cascade Range must have been carried by these same winds over the crest.

Snow, unlike water, falls to the ground as a light fluffy solid and for this reason may be picked up by the winds and drifted over the crest of divides. Thus, for instance along the peak of a house we find that the heaviest snow is on the leeward side of the roof. On a mountain, in a

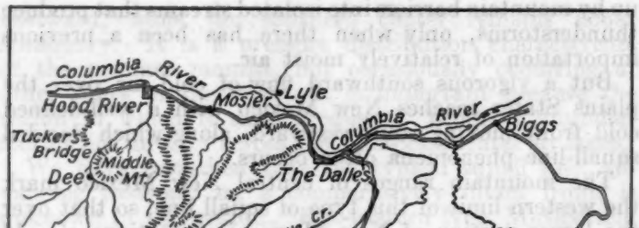


FIGURE 1.—The Dalles formation. This formation is composed of material derived from the Cascade Mountains and is evidence of a time when the water and ice supply was abundant. In The Dalles formation are glacial erratics that prove that glaciers from the Cascade Mountains extended far to the east

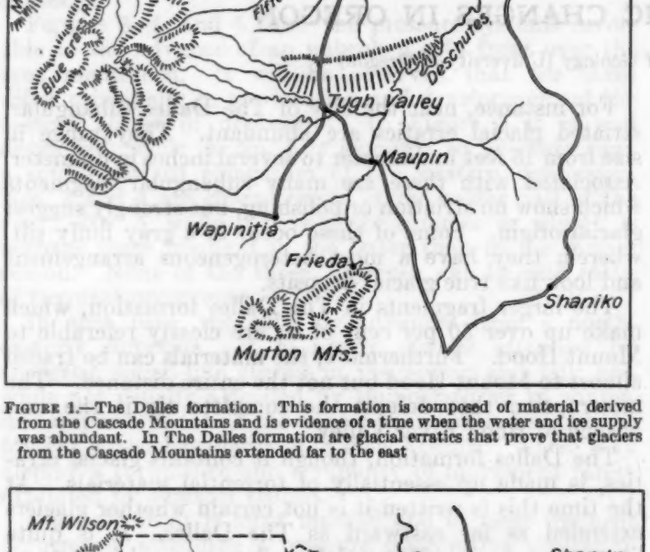


FIGURE 2.—The Madras formation. This formation is similar to The Dalles formation and gives evidence of a large supply of water and the presence of glacial ice in early Pleistocene times. It does not, however, like The Dalles formation, furnish direct proof that the glaciers extended more than a few miles to the east of the Cascade Divide

similar fashion, most of the snow is drifted to the leeside. Further, the higher the mountain, the further leeward the cloud banner will soar. Hence, if a range is high enough so that all precipitation occurs in the form of snow, much of it will drift over the divide. One would expect, therefore, that during the glacial period great glaciers must have been on the east side of the mountains of the Cascades. Existing evidence on such mountains as

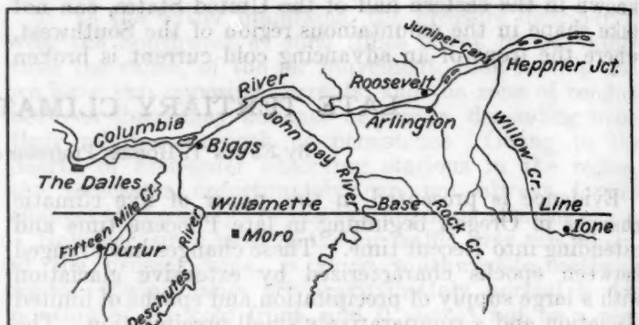


FIGURE 3.—The Arlington Lake beds contain both lake beds and stream gravels and furnish evidence of a period of extensive flooding of the Cascade Range at a time contemporaneous with the deposition of The Dalles and Madras formations. The Arlington Lake beds lie beneath extensive morainal deposits and bear on their surface enormous glacial erratics

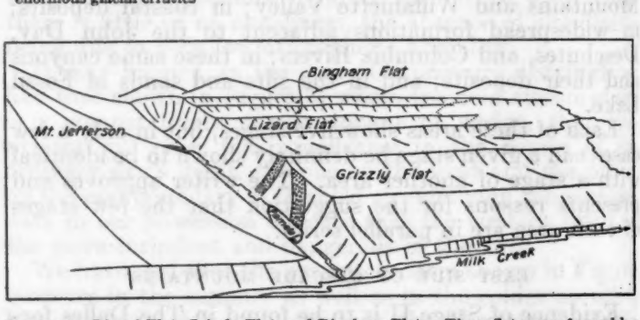


FIGURE 4.—Lizard Flat, Grizzly Flat, and Bingham Flat. These flats were formed by truncation of the upland lying east of Mount Jefferson. These glacially formed flats are now separated from Mount Jefferson by glacial valleys that lie almost at right angles to their slope. They give evidence therefore of two periods of glaciation in the Mount Jefferson region

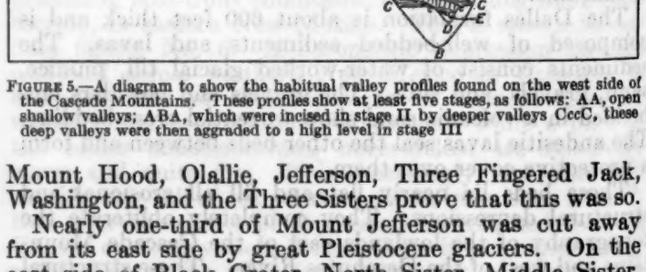


FIGURE 5.—A diagram to show the habitual valley profiles found on the west side of the Cascade Mountains. These profiles show at least five stages, as follows: AA, open shallow valleys; ABA, which were incised in stage II by deeper valleys CccC, these deep valleys were then aggraded to a high level in stage III

Mount Hood, Olallie, Jefferson, Three Fingered Jack, Washington, and the Three Sisters prove that this was so.

Nearly one-third of Mount Jefferson was cut away from its east side by great Pleistocene glaciers. On the east side of Black Crater, North Sister, Middle Sister, South Sister, and Broken Top an immense glacier extended far to the east beyond the present timber line. Over this area the rocks are intensely scoured and heavily mantled with glacial deposits. Only a half-cone of the Middle Sister, with the flat face to the east, remains from erosion during the ice age. All of the Elder Middle Sister was

cut away with the exception of that standing beneath the cone of the present Middle Sister. The bergschrund wall cut by the former glaciers rises almost perpendicularly for 1,200 feet.

There are several facts which prove that East Fork of Hood River was not in existence at that time. Suffice to point out here that had it been in existence the following should be true: (1) The valley would be glacially carved throughout its entire length; (2) the side walls would show evidence of a glacier passing over them and rounded them; (3) there would be no hanging glacial troughs like Crane Prairie and Bonney Meadow.[1]

Dealing with the same area, we find evidence of a Stage III. The glaciers of the first epoch must have retreated at least to Blue Grass Ridge, and water which escaped from them, dammed by recessional moraines and perhaps lava flows, was diverted northward toward the main Hood Valley. The glacier held its restricted position long enough to cut a valley 3,000 feet deep.

Continuing to fix our attention on the same area, we find positive proof of another glacial advance and stage IV. This glaciation was not as extensive as the former. The ice advanced on the east side of the East Fork of Hood River and moved down it for several miles. The east-side glaciers did not cut a glacial valley long enough to open up into the older main glacial valley of Hood River.

Stage V is shown by the cessation of glaciation. Since that time the glaciers have diminished and now form tiny patches on the east slope of Mount Hood.

The five stages shown by The Dalles formation and the country east of Mount Hood is also shown farther south on the east side of the Cascade Mountains.

South of the Mutton Mountains is the Madras formation. (Fig. 2.) This formation extends southward almost to Bend, Oreg., and lies west of the Deschutes River and beyond its junction with the Crooked River and it lies west of the latter. The Madras formation closely resembles The Dalles formation. Its component beds lie almost flat. These consist of torrential beds of sands, gravels, pumice,and pyroclastics which lie between very uniform basaltic and andesitic lava flows. These flows have sealed in the torrential beds and serve as a protection for them. Toward the Cascade Mountains the uppermost lava flows become andesitic. The Madras formation fills structural and erosional depressions that are younger than the Columbia River basalt formation. No glacial erratics have been found in the Madras formation, but the gravels contain the same rocks and in about the same proportion as in the moraines which lie farther west. This formation has been examined during the field season almost daily over a period of three years and so far no erratics have been found. The torrential nature of the formation leads to the opinion that it is strictly a torrential deposit made by great quantities of water from streams that were forced to aggrade on a large scale in depressions. In fact, it looks as though sheet-water aggradation took place over a large area on the eastern side of the Cascade Mountains.

If the Madras and The Dalles formations are equivalent in time both may represent aggradational activity during the first glacial stage. In support of this conclusion let us now examine the Arlington Lake beds. (Fig. 3.) These beds occur on the south side and very close to the Columbia River. They are best preserved between Willow Creek and Blalock Canyon. They form beds not over 200 feet thick that lie perfectly flat. They consist of excellently bedded white ash, diatomaceous material, and gray silts. The bottom members contain 1 to 6 inches of water-worn pebbles, many of which are derived evidently from the Cascade Mountains. These beds are greatly eroded, but they once extended as far south as the Willamette base line, as far north as the north side of the Columbia River, an unknown distance east, and as far west as The Dalles beds, since they, too, lie absolutely flat. The Arlington beds are the result of some sort of ponding not long ago.

Observers over several years who have examined The Dalles, Madras, and Arlington beds have all become convinced that they were formed at the same time and by the same agency. The conviction prevails that they represent a period of aggradation during the first glacial stage.

The Madras and The Dalles formations thus give evidence of two climatic stages. Deep canyons cut in all of these formations show Stage III. These canyons indicate a rejuvenation process. Since all the beds of the three formations lie nearly flat, the canyon cutting is not due to any local uplift. Various explanations can be suggested but one not involving change of level would explain the change from aggradation to degradation. For example, if a glacial stage disappeared the amount of water in comparison to the amount of débris given to the stream would have been augmented, the transportation power of the streams accelerated, and canyons would have been cut.

It is not necessary, in support of the thesis of this paper to agree with the explanation given in the above paragraph. It is essential here to note that the age of the canyons is post The Dalles formation. These canyons and the upland surface on either side contain glacial erratics. The erratics are postcanyon and represent the last glacial stage.

These erratics consist of old weathered basalt, limestone, boitite-granite, granite-gneiss, quartzite, schist, and slate. They lie on only the surface of The Dalles and of the Arlington Lake beds, and despite our extensive studies such glacial erratics of these rock types have never been found within The Dalles or Arlington beds. The glacial erratics within these beds are of Cascade Mountain origin whereas those that lie on the surface are of foreign origin. Furthermore, the erratics within the beds are found no farther east than Five Mile Creek, in the vicinity of The Dalles.

The glacial erratics that lie on the surface have been found on both sides of the Columbia River from Willow Creek, Oreg., to The Dalles. On the John Day River they have been found as far south as Buckskin Canyon, T. 4 S., R. 18 E., elevation 1,000 feet. They are also quite common from McDonald to the mouth of the Columbia River. A large erratic of granite 5 by 2 feet and other smaller ones were found as far south as Sherar Bridge, on the Deschutes, practically as far south and at the same elevation as the occurrence on the John Day River. They were found rarely, however, from Sherar Bridge to the mouth of the Deschutes River. If the John Day and Deschutes Rivers were flooded so that the flood in their lower portion reach to their 1,000-foot contour, then such a flood would rise over the south rim of the Columbia River canyon from Willow Creek to The Dalles. Without attempting to discuss the subject fully, it is evident that flooded water conveying ice blocks bearing glacial erratics occupied these canyons at a date later than the canyons and later than The Dalles and Arlington beds. They definitely prove a later glacial stage.

[1] There is some evidence that the events of this first stage were even more complex and that great flows of andesitic lava poured eastward, burying in part The Dalles formation. The study on this phase of the problem is not complete.

On the walls of the canyons of three streams gravel bars are perched, and on the Columbia River there are in addition perched deltas. These high bars may also be related to this last glacial stage. Mastodon bones were found in one bar opposite Fargher, proving their Pleistocene or Pliocene age. These high bars and deltas may be properly related to the same glacial stage as the erratics.

The history recorded since that time is one of aggradation.

A summary of the evidence thus far presented shows five stages wherein the climate changed. These changes are (1) from the closing Pliocene to (2) an early glacial state, (3) to an interglacial stage, (4) to a second glacial stage, (5) to a recent aggradational stage.

### CASCADE MOUNTAIN UPLAND

Evidence in support of glacial stages was first found by the writer and reported [2] as early as 1925 on the Cascade Mountain upland. Here, in addition, there is further proof of glacial stages.

There is abundant evidence of an extensive glaciation above 4,500 feet on the Cascade Mountains extending at least from Crater Lake on the south to Mount Hood on the north. The numerous peaks, even the small ones like Olallie Butte, bear large cirques, usually on the east side. The larger peaks are badly dissected and, in the case of some of them, like the North and Middle Sisters, are more than half destroyed. The surface of the plateau proper bears many roches moutonnées, erratics, moraines, and striæ. In the vicinity of Diamond Peak, Three Sisters, Mount Jefferson, and Mount Hood, where the writer has made his most detailed studies, the evidence points to a continuous mass of ice covering the entire upland surface. The fact of this extensive glaciation was first described by the writer.[3]

We will describe the evidence of glacial stages beginning with Mount Hood. North, northwest, and west of Mount Hood are glacially carved valleys and glacial deposits now separated from Mount Hood by more recently cut valleys and by thick aggradation deposits. Thus, upper Hood River Valley is of glacial form and its lower end, where constricted by Middle Mountain (see fig. 1) contains an old buried moraine. This moraine was traced as far north as Tucker's Bridge. The valley is separated from Mount Hood by later lava flows and aggraded sediments which in turn are cut by stream valleys.

Bull Run Lake is northwest of Mount Hood, lies in a typical glacial valley, and is dammed in by a moraine. The extension of that valley may be traced toward Mount Hood only as far as Sentinel Peak and Hiyu Mountain. The intervening distance of 7 miles is an area now deeply dissected by streams, the chief ones of which lie athwart the older drainage system. The west fork of Hood River and the Clear Fork of Sandy River, in fact, lie so contrary to the normal drainage slopes that some reason must be assigned for their abnormal position. On Sandy River morainal material may be traced almost to Cherryville.

In the case of Hood River Valley and the old Bull Run Lake Valley the glacier must have retreated far up the sides of Mount Hood. The water from the diminished glaciers was dammed by moraines and forced to flow a long way around to find an outlet. These diverted streams attached themselves to Hood and Sandy Rivers and have since realtered the older glacial topography.

In Hood River Valley we have further proof of this interglacial stage. Thus, from the junction of the Middle and West Fork of Hood River to Tucker Bridge bedded water-worn gravels and sands lie on top of morainal material. These torrential deposits do not lie on a hummocky morainal surface, but upon a smooth eroded plane, proving that the interglacial stage existed long enough not only to deposit an extensive valley fill but to cut away what must have been a large terminal moraine.

Two types of evidence exist, proving that a second glaciation took place in the Mount Hood region. First, near Dee, in Hood River Valley, glacial till lies on top of the interglacial beds. This last till is quite widespread and can be traced from Dee up all the branches of Hood River Valley.

The glacier of the second stage advanced down the newly formed V-shaped valleys but not as far as those of the first.

These glaciers cut the glacial valleys of East Fork of Hood River, White River, Salmon River, Zigzag, and Sandy Rivers. Only in the last two valleys did the glacier reach an earlier glacial valley. In fact only in the last two cases were the valleys that were cut by interglacial streams occupied by glaciers.

Since the second glacial stage the general events have been aggradation, accompanied by a retreat of the glaciers,[4] there have been minor glacial fluctuations. Thus, White River Valley shows in its upper portion morainal material covered with a 10-foot bed of soil. Lying on the soil are trees up to 1½ feet in diameter. This jumble of trees is now overlain by a 250-foot thickness of fluviatile material.

The five climatic stages so clearly shown in the vicinity of Mount Hood are found in other parts of the Cascades.

One evidence of this great ice cap is to be found about Mount Jefferson. Here the evidence is clear that the valleys were all filled to overflowing by one immense and continuous glacier which moved eastward and westward over the entire surface. In the early Pleistocene, instead of many individual or isolated glaciers surrounding Mount Jefferson, one great glacier entirely mantled its slopes and extended outward to a distance of 10 miles and down the valley for 20 miles. Only a few of the highest of the surrounding peaks were overtopped by this ice.

Another proof of this great Pleistocene glacier is the surface of Grizzly, Lizard, and Bingham Flats, near Mount Jefferson. (Fig. 4.) Standing on the west side of Mount Jefferson and looking to the west one notes that Hunts Cove and Hunts Cove Creek Valley is a distinct glacial valley extending north and south. Likewise, the Marion Creek fork of the Santiam is a typical north and south glaciated valley. Between these two great north and south valleys are Grizzly, Lizard, and Bingham Flats. Grizzly Flat, for instance, is not one continuous flat surface, such as one might expect from

[2] Hodge, E. T. Geology of Mount Jefferson, Mazama, December, 1925, Vol. VII, No. 2, pp. 26–38.
[3] Hodge, E. T. Mount Multnomah, Univ. of Oreg. publication, 1925.

[4] Glacier studies in the Cascade Mountains have been limited in quantity and devoted exclusively to Recent glacial features.
1. Coleman, E. T. Glaciers in Oregon and Washington, Alpine Jour., 1877, p. 233.
2. Fairchild, H. L. Evidence of Ice Erosion from the Cascades, U. S. G. Soc. Amer. Bull. 16: 39–41, 1905–6.
3. Hodge, E. T. 1925, loc. cit.
4. Reid, Harry Fielding. Jour. Geol., p. 261, 1904.
5. Russell, I. C. U. S. G. S. Bull. 252, p. 124, 1905.
Glaciers Existing in U. S., Oregon, U. S. G. S., 5th Annual Report, pp. 339–341, 1883–84.
Glaciers of North Amer., Ginn & Co., pp. 67–70, 1897. Notes on glaciers on Mount Hood, also Mounts Jefferson, Diamond Peak, and Three Sisters.
6. Stadter, F. W. Mazama Annual, 1925.
7. Williams, Ira A. Glaciers of the Three Sisters, Oreg., Mazama, 5: 14–23, December, 1916.

its name, but a series of gentle troughs, the axes of which extend east and west, as shown in Figure 4. A glacier evidently moved directly west over any preexisting divides and plowed these broad, gentle furrows. This glacier must have been 2,000 feet deep in order to move over and truncate such high divides. Grizzly Flat, Lizard Flat, on the west, Bingham Basin on the southwest, the flat between the middle forks of Jefferson Creek on the southeast, and a number of smaller flats at the base of the mountain on the northwest, west, and southwest were planed by this early Pleistocene glacier.

Because the west side of the Cascades was more dissected by stream valleys than the east side, tongues from the ice sheet were concentrated in long glacial streams which moved down these valleys for long distances. The total surface covered by ice was, however, much less than on the east side of the "break." On the west side of Mount Jefferson the glaciers extended as far west as Detroit and reached an elevation of 2,300 feet.

The evidence in the Mount Jefferson region of an interglacial stage is similar to that in Mount Hood in regard to the east fork of Hood River. The profiles characteristic of the lower valleys and which reveal the climatic stages, of course, are not to be found in the upper valleys or along the crest of the Cascade Range. However, in these higher elevations there is evidence that older glaciated surfaces were at a later time free of ice and eroded by streams. Thus, Hunts Cove Valley, on the west side of Mount Jefferson, is incised in the high surface of and early glacial planation represented by Grizzly, Lizard, and Bingham Flats. This older upland glacial surface may be called the first glacial surface.

The Hunts Cove valley must be younger than the first glacial surface, because a topographic unconformity exists between its valley walls and the older upland glaciated surface. A glacier moved westward from the divide across this upland and planed it. It then retreated, forming moraines, behind which its waters were diverted. The diverted waters cut new valleys almost at right angles to the former glacial course. The glacier, upon readvancing, followed the new valleys and glaciated them.

Jefferson Park is another bit of evidence of an interglacial epoch. Beyond the ridge anchored by east and west Park Butte there is abundant evidence that at one time ice moved northward for several miles before swinging west and east down the Cascade slopes. This evidence is that of striæ, roches moutonnées, and moraines. If Jefferson Park had been in existence during this period of glacial erosion, it is evident that, due to the steep east and west slopes, most of the ice would have moved east and west and cut the valley so deep that none would have overridden the east and west Park Butte Ridge. The valley must have been cut later and in a manner similar to that of Hunts Cove.

The same stages have not been observed in the Three Sisters region, but there is evidence of an early extreme glaciation. For instance, all the area on the south side between the South Sister and the Rampart shows evidence of glaciation. Here much of the glaciated surface is concealed by young lava flows called Rock Mesa, Devils Hill, and Newbery Flow. Nevertheless, at the edge of Rock Mesa one can see where the lava poured out over glaciated rocks. Again, to the north of the Three Sisters where "islands" rise through Belknap and Jerry Flows, the surface of these "islands" shows glacial striæ. If one could remove the great McKenzie lava flood which covers most of this area one would find, no doubt, beneath it roches moutonnées, polished rocks, striations, and glaciated bowlders. A great glacier covered the west side of the Three Sisters through which only the large peaks emerged. The great cirques and glacially carved walls indicate that this glacier extended westward, abutting against the Husband, which, acting as a cleaver, split this glacier in two parts, one part of which moved down Lost Creek Valley and the other moved down Separation Creek Valley. The west side of the Husband bears large cirques, and the area beyond is glaciated for about 5 miles. To the north a great stream of ice moved down the Santiam as far west as Cascadia on the south fork of the Santiam. Thus, the last moraine on the middle fork of the Willamette is at Rigdon, at 2,445 elevation, and on the McKenzie rim, at Belknap Springs.

### VALLEYS ON WEST SIDE OF CASCADE MOUNTAINS

The evidence now to be presented has to do with profiles of and deposits in the valleys on the west side of the Cascade Mountains. The time at which the five post-Pliocene stages occurred are not known except by such correlation with the glacial stages just cited.

The correlation attempted depends upon the interpretation made of the valley profiles. Were the streams aggrading or degrading during the periods of mountain glaciation? In seeking an explanation by comparison with other parts of the world we must remember that we are dealing with streams that had their origin in mountain and not continental glaciation. These streams also were influenced by changes in gradient. Unlike the streams on the east side of the Cascades, these had a comparatively free outlet to the sea. Further, there is the factor that a stream may degrade in one portion of its course and aggrade in another during the same period of time. For the purpose of this paper an assumption is made which it is hoped future discussion will justify. It is assumed that the cause of glaciation was increased rainfall, resulting from an uplift of the Cascade Mountains. The ice resulting from this increased rainfall inhibited general mountain erosion to such an extent that the streams, with their increased gradient and water supply, were able to engage in erosion. During interglacial stages, for the same reason, rainfall was decreased and streams were supplied not only with débris then freed from the glaciers but by the material furnished by renewed upland erosion. The reduced rainfall and gradient and increased débris caused the streams to aggrade.

Before the glaciers appeared—that is, at the close of the Pliocene—the upland surface had been subjected to a long period of erosion. The valleys produced valley profiles AA, in Figure 5. This represents stage I, a period of comparatively smaller precipitation. The advent of glaciation, stage II, greatly increased the erosion power of the stream.

The rivers had cut deep gorges in the bottoms of the Pliocene valleys. These gorges, incised in still older valleys, may be seen in all parts of the Cascades and represent that portion as shown in Figure 5 from ABA.

Great rainfall, which produced the glaciers of the first stage and deepened the valleys of the Cascades and Coast Range, carried to the sea great volumes of débris. At the end of this time there must have been left on the higher slopes large amounts of wasted material eroded but not entirely removed. The gradient of the stream having been reduced, the decreased rainfall of the interice stage caused the streams to aggrade their valleys with the

material brought to them by the mountain streams of high gradient.

In the valleys of the McKenzie, the Santiam, and other valleys of the Cascades definite evidence is given of the aggradation on the west side of these valleys, as indicated in Figure 5 CccC. Thus, this aggradation begins in the Santiam at about the mouth of Tunnel Creek. Here, about 9 miles from Detroit and at an elevation of 2,400 feet, the valley is broad and low terraces occur on either side of the stream. These silts and gravels accumulated in the Santiam may be traced along the sides of this valley to its mouth as benches.

Following this reasoning to its logical conclusion, we may explain CDC in Figure 5 by a redevelopment of those conditions which produced glaciation, such as increased precipitation. Because of the increased size of the glaciers and increased rainfall at lower elevations the streams again became swollen. The increased volume of water permitted the streams to again engage in down cutting in all the valleys on the west side of the Cascades. Thus, west of Mount Jefferson the results of this down cutting are to be noted in the river-cut terraces along the streams. The streams were able to remove much of the material deposited in their valleys, in some places all down to bedrock, and in other places the streams were superimposed on side-wall spurs, but in most places only terraces were cut in the older flood plains.

In Recent times, with the decrease in precipitation and the shrinkage of the glaciers, the eroding and transportation power of the streams has diminished. The streams on the west side of the Cascade Mountains are all overloaded and are again filling their channels with muds, sands, and gravels (fig. 5, D–E) but have not as yet had time to fill their valleys up to the level of interglacial times. On the steeper slopes the gradient and volume of the stream is sufficient, as a yearly average, to enable the streams to erode. This is shown by notches cut in the edges of the glacial steps.

### WILLAMETTE VALLEY

The evidence of five stages in the Willamette Valley, each correlated with those so far described, is almost identical with its tributary valleys on the west side of the Cascade Mountains. The thalwags of the Willamette Valley are identical with the mountain valleys, but the former are much more difficult to detect.

The interglacial aggradational stage has left an interesting record. The Willamette Valley at Portland was aggraded to 300 feet above the present river level. Along the Valley near Portland are important terraces. Terraces are uncommon in the upper valley, but here and there, perched on the valley walls, are small river deposits. The height of aggradation is shown by waterworn pebbles and gravels which may be found lying on the top of the many isolated buttes which stand in the valley. Thus, on Skinner, Honeysuckle and Gillespie Buttes near Eugene the gravels were first noted by the writer lying at 100 feet above the present valley floor. Bretz [5] has described a Satsop formation to which he assigns the gravels along the Columbia River, on the Sandy River, and elsewhere in Oregon and in many places in Washington. His description is typical of gravel terraces common along all the rivers in western Oregon. Those described by Bretz, in Oregon, and all others examined by the writer lie in rock-bound valleys and can be no other than the deposits made by stream aggradation during an interglacial stage.

Much of this aggraded material was removed by the swollen waters of the succeeding ice stage. The material eroded from the upper valleys was carried downstream and deposited at the coast or in the slack waters of the lower river. The Columbia River was particularly overloaded because of immense deposits of aggraded material east of the Cascade Mountains. The high flood waters due to choking of the lower course of the Columbia and due to periodic floods (produced when warm, heavy rains fell on the great glacier and snow covered uplands) were high enough to reach the rim of the valley walls. Floods of about 50 feet are common even at the present time, and the river lies 300 feet below its former level at Portland. In an ice age, with a river choked in its lower course, floods may have been high enough to pond all the main river between Columbia, Deschutes, and John Day, in Oregon.

The fact of the flooding has been observed before; but the date of it has never been fixed, and the cause has been explained as subsidence.[6] The complete absence of marine or brackish-water fossils seem to eliminate the subsidence theory.

Glacial erratics occur in the Willamette Valley lying on top of the terrace deposits. They are found nearly as far south as Eugene. The materials are of rocks not known to occur either in the Cascade Mountains or the Coast Range of Oregon and are identical with similar erratics found along the Columbia River east of the Cascade Mountains. The most probable theory as to their origin seems to be as ice-floated erratics derived from glaciers in the upper Columbia River Valley. Their deposition was concurrent with the erosion of terrace deposits at the time of the second glacial stage.

The fifth climatic change in the Willamette Valley is shown by the present aggradational work of the streams resulting from a reduced amount of precipitation.

If we now compare the valleys on the west side of the Cascade Mountains with those on the east we find them presenting the same evidence, with two exceptions. The valleys on the east side of the Cascade Mountains do not show the Pliocene and early Pleistocene profiles, because they are now buried beneath the great aggradational deposits of the Madras and The Dalles formations. There is sufficient evidence, however, that these deposits do fill erosional depressions probably cut at these periods. The greater extent and thickness of the deposits on the east side may be accounted for by two conditions—one, that the valleys on the east side, unlike those on the west, had no convenient outlet to the sea, and, two, the streams on the east side, for reasons already cited, were supplied with a greater supply of glacial débris.

### OREGON COAST DEPOSITS

The amount of precipitation over an area at a given stage of elevation determines the amount of erosion and transportation that will take place. If the precipitation is great the stream will erode the uplands and carry all

[5] Bretz, J. Harlan. Journ. Geol., XXV, No. 5, pp. 446–459, 1917.
The late Pleistocene Submergence in the Columbia Valley of Oregon and Washington, Jour. Geol., vol. 37, No. 7, October–November, 1919.
The Satsop Formation of Oregon and Washington, Jour. Geol., 25:446–458, July–August, 1917. Abstract, Geol. Soc. Amer. Bull. 28:170–71, Mar. 31, 1917.

[6] Condon, Thomas. The Willamette Sound, The Overland Monthly, 7:468–473, 1871. (A chapter from Two Islands.)
The Two Islands and what became of them. Portland, Oreg., 1902.
Oregon Geology, a revision of The Two Islands, with a few tributes to the life and work of the author, by Ellen Condon McCormack. 2d ed. Portland, Oreg. J. K. Gill Co., 1910.
Collier, Arthur J. The Two Islands, Univ. of Oreg. Monthly, 8:48–50, November, 1902, No. 2. A review of Professor Condon's book.
Smith, W. D., and Packard, E. L. Salient features of the geology of Oregon. Univ. Oreg. Bull., n. s. 16, No. 7, 1919.
Jour. Geol., 27:79–120, 1919.

of their load to the sea; if small, the load will be deposited in the valleys and very little material will reach the sea. Therefore, of the five stages here considered, there would have been no deposits made along the Oregon coast during three of them. Only during the two ice stages would the streams have carried their entire load to the coast.

The deposits which may be assigned to these two glacial stages, and the break between them, have been noted by several observers.[7] Diller, Arnold and Hannibal, and Martin observed the deposits at the mouth of Elk River and gave to them a Pleistocene age. A difference of opinion exists between these observers as to the early or late Pleistocene age of these deposits—a difference of opinion quite natural in view of the fact that a disconformity exists between the lower shell, sands and gravel beds (10 to 100 feet), and the upper gravel beds (5 to 15 feet). These same beds are found at several places along the coast as far north as the Columbia River.

At Cape Blanco, J. P. Smith, Martin, and W. D. Smith and E. L. Packard have described two formations overlying the Pliocene Empire formation. The lower or Cape Blanco beds are composed of shell beds, conglomerates, and sands. Disconformably overlying these is the "Elk River" beds of Martin and Arnold and Hannibal. The author thinks the Cape Blanco here is the equivalent of the lower Elk River beds at Elk River and the equivalent of the lower set of beds unnamed at other places along the coast. The "Elk River" at Cape Blanco corresponds to the upper portion of the Elk River elsewhere.

### EASTERN OREGON LAKES

Finally, and in brief, one lake at least shows evidence of these five stages. Fossil Lake contains fossils of Pleistocene age [8] consisting of fish, camels, horses, mammoths, birds, and other animals. These have been found by the writer to occur in two distinct groups and to lie, respectively, in two different lake levels. Since no fossils of pre-Pleistocene age have been found, we may presume that the lake came into existence with Cascade Mountain glaciation, as follows: The largest glaciers were on the east side of the Cascade Mountains. The winter winds then and now are the rain bearers, but the present summer winds are undersaturated. The summer Pacific Pleistocene winds, nearly saturated, were completely saturated in passing over the glaciers, melting in the hot summer sun.

These saturated summer winds moving eastward over the high plateaus of eastern Oregon were disturbed by the rising convection columns of air produced on this high flat area. The saturated winds descending from the melting glaciers were mixed with rising convection currents brought to saturation by decrease in temperature of air. This mixture of saturated air masses of different temperatures would give rise to summer cyclonic thunderstorms, such as are now common in the vicinity of the Blue Mountains of Oregon and in Colorado during the month of August. By reason of the moisture added by the glaciers these mixed currents of air were capable of yielding more moisture than at the present time and consequently gave rise to great lakes in eastern Oregon. Such lakes would correspond to the ice stages, and from the last ice stage to the present time Fossil Lake, in harmony with all of Oregon, has desiccated; it is now completely dry and imminent to burial by the surrounding desert sands.

### CORRELATION

The correlation of these five stages must be based to a large extent upon the mechanics involved and which have already been stated. There is not sufficient evidence to warrant correlating these stages with other Pleistocene epochs on the Pacific coast. In British Columbia, Dawson,[9] and in the State of Washington, Willis,[9] and Bretz [9] have found definite evidence of only two periods of glaciation, separated by one interglacial period. Matthes [9] has noted the same epochs in the Sierra Nevadas. In the Oregon Cascade Mountains and at the above localities the first ice epoch is very much older than the second ice epoch. This is shown by the weathered glacial surface, the decayed moraines, and its deep burial below the deposits of the interglacial epoch. So far no definite evidence has been found which definitely proves that this older glacial epoch was not preceded by still earlier glaciations. Because of its extensive and intensive character it may have destroyed so much of the evidence of earlier glaciations that their existence may not be proven without more detailed searches being made.

The best chance of making a correlation is with the glacial epochs in Washington, and it may be that the three Pleistocene stages noted in Oregon are identical with the Admiralty (oldest ice epoch), Puyallup (interglacial epoch), and Vashon (youngest glacial epoch) of that State.

Until such a time as a complete correlation can be made it is proposed to call these epochs as follows:

Recent—period of aggradation and small precipitation.
Jeffersonian—epoch of glaciation and great precipitation.
Williamettian—epoch of aggradation and comparably small precipitation.
Cascadian—epoch of glaciation.
Late Pliocene—epoch of erosion and small precipitation.

The Jeffersonian epoch may be identical with the Wisconsin of North America. The glacial erratics in the Willamette, Deschutes, John Day, and Columbia River Valleys are not referable to any known Oregon source. If they were furnished by the continental glacier of Northern Washington and British Columbia they must have been furnished at Wisconsin time and thus gave to Oregon one tie with continental glaciation.

[7] Arnold, R., and Hannibal, H. Proc. Amer. Phil. Soc., vol. 52, p. 505, 1913.
Diller, J. S. U. S. Geol. Survey Bull., 196, p. 31, 1902.
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Smith and Packard. Loc. cit., 1919.

[8] Cope, E. C. Am. Natural. XXXIII, 970-82.
Condon, Thos. Referred to by Smith and Packard, 1919, loc. cit.
Shufeldt, R. W. Jour. Acad. Nat. Sci., Philadelphia, No. 9, 1892.
New and extinct birds and other species from the Pleistocene of Oregon, Sci. New Ser., 37:306-307, Feb. 21, 1913.

[9] Bretz, J. Harlan. 1908, 1913, loc. cit.
Glaciation of Puget Sound, Bull. Wash. State Geol. Survey, No. 8; Bull. No. 13, Wash. Geol. Survey.
Dawson, G. M. Physiographic Geology of the Rocky Mountain Region, Trans. Royal Soc. Canada, Vol. VIII, 1890, sec. 4, pp. 3-74.
Matthes, F. E. Science, p. 550, 1925.
Willis, Bailey. Physiography and Deformation of Wenache, Chelon Dist., loc. cit.
Drift Phenomena of Puget Sound, Bull. Geol. Soc. Amer., vol. 9, 1897. Willis first employed the terms Admiralty, Puyallup, and Vashon.

# METEOROLOGICAL INVESTIGATIONS IN GREENLAND DURING 1930–31

By LEONARD R. SCHNEIDER

Meteorologists in charge of preparations for the 1932–33 year of Arctic study will have to extend themselves if they are to equal the interest and activity being shown in Greenland at the close of the summer of 1930 where to-day there are four expeditions already at work on, or in the vicinity of, the great inland ice cap. In all, five nations are represented. In the following paragraphs something of the purposes of, and difficulties encountered by, the expeditions will be summarized.

The German expedition led by Dr. Alfred Wegener has as its goal the establishment of three meteorological stations in latitude 71°. One station, on the western slope of the inland ice, was early set in operation, and during the last weeks of summer all energies were concentrated upon the huge task of getting equipment from the coast eastward to an elevation of approximately 10,000 feet and at a point 250 miles into the interior. One hundred dogs, Icelandic ponies, and newly devised propeller-driven motor sledges were used to transport the freight. Dr. Walter Kopp is in charge of the station located on the ice cap at its eastern margin; Doctor Georgii is taking over the work at the remote interior station; and though Doctors Weiken, Lowee, and Wegener are in the region, their exact field of operation is unknown to the writer.

Using Sir Ernest Shackleton's ship, *Quest*, Col. H. George Watkins, director of the British Arctic Air Route Expedition, has spent the past summer at work along the eastern coast of southern Greenland. The party, at Angmagsalik on the east coast, in latitude 66°, set up its base on Sermilikfjord, and immediately the expedition began its ambitious program. Quoting from the New York Times, we read:

> The airplane will start on the first flight north, up the coast from the base for about 100 miles, taking vertical and oblique photographs of the coast line. When it comes back it will be put on board the *Quest*, and the *Quest* will move up that 100 miles, and the airplane will repeat the process for the next 100 miles. In this way the 320 miles between Angmagsalik and Kangerdlugsuak Fjord, which may be a very large and deep fjord, will be surveyed from the air.

In the meantime Scott, Rymill, Lindsay, Bingham, and Chief Meteorologist Riley, will establish a central ice-cap station, where as in this case of Wegener's, the meteorological observations will be continued for one year. It is further proposed—

> About the end of August or the beginning of September, Scott and I (Watkins) and two others will start on a journey by dog sledge down the edge of the ice cap to the south. We shall travel as near to the coast as the crevasses on the edge of the ice allow. That is to say, our route will lie through the nunataks, which are the tips of mountains sprouting through the ice cap at the heads of the glaciers. On our right as we go south will lie the smooth, monotonous sheet of the ice cap. When we reach the south (it is impossible to tell how near the point we shall get) we shall turn north up the highest part of the ice cap and follow the ridge until we get to the central ice-cap station opposite our base. We shall then turn out and drop down to the base.
>
> The most important purpose of this journey will be to find out which is the highest part of the ice cap, to delineate, as it were, its profile.

But still further work is outlined for the expedition. With the coming of spring, six or eight dog sledges will begin a 1,800-mile trek northward over the great ice plateau. Also at this time of the year an airplane will fly from the base station westward to Godhavn.

United States' representative in the Greenland activity is again directed by Prof. W. H. Hobbs, of the University of Michigan. To Doctor Hobbs belongs the credit of having established the first aërological station to be in continuous operation for the study of the upper air in Greenland. His 1930 expedition, the fourth successive party sent into the field, has had its members sent to two different places along the west Greenland coast. William S. Carlson, A. B., and assistant Max Demorest, have set up a station at east Angtilagtok, near Upernivik, in latitude 73°, the site being only 14 miles from the west margin of the ice cap. The second station was established at Ivigtut, in latitude 51°, and is in charge of Evans Schmeling. Both Carlson and Schmeling became interested in the study of meteorology through their work at Mount Evans, the former base of Doctor Hobbs' expeditions. In addition to their work of making pilot-balloon ascensions and gathering meteorological data, these men will determine in their respective regions the exact position of the ice front. Near Upernivik, in particular Professor Tarr 30 years ago determined the frontal position of the Cornell Glacier, and Carlson's findings, therefore, should be exceedingly valuable.

Two other nations, namely, Norway and Rumania, will be represented if Dr. Th. Hesselberg, of the Norwegian Meteorological Institute, finds it possible to establish a station for the study of upper air on MacKenzie Bay, in latitude 73½°, and if Doctor Dambrov, of Bucharest, carries out the plans he has given for his east Greenland weather station. At this time it is not known whether some of the Danish-operated Greenland stations plan to send up pilot balloons.

Heretofore, Greenland meteorological records gathered by expeditions which chanced into the field have had only a limited value, for in a region as large as the eastern part of the United States east of the Mississippi only samples of the weather could be gotten, and a definite conclusion regarding the so-important general circulation was practically unobtainable. It is for this reason, then, that during the year 1930–31, through cooperation, the stations of the Norwegian, German, Rumanian, and British on the east coast, the remote interior ice-cap stations of the German and British, and the west-coast stations of the German, and of the University of Michigan, together with the Danish coastal stations, should yield a vast amount of valuable weather data. From these data ought to come new conclusions regarding the weather of Greenland and surrounding regions, information needed not only for the trans-Atlantic air lines, but for what is more significant, a correct analysis of the weather of the Northern Hemisphere.

## SWEDISH EXPEDITION TO THE NORTH ATLANTIC GULF STREAM

By LEONARD R. SCHNEIDER

After a successful three months' cruise during June, July, and August in 1929, Dr. J. W. Sandström's 1930 summer expedition into the North Atlantic Gulf Stream area came to an end 43 days after the party had embarked. Engine failure only 18 days from port caused the *Rane* to be turned about, and some 15 days later, under sail, the vessel reached the Norwegian town, Bodo, where repairs were made. From Bodo the vessel returned to Sweden.

This information appears in a feature article in the October 14 issue of the Dagens Nyheter, a Stockholm daily. Further items of interest contained in both the article and its accompanying map are given in what follows.

Doctor Sandström's expedition left western Sweden on July 24, heading for the Shetland Islands and Iceland. Near the Skagerak and in the North Sea the surface water was found to be unusually warm, the temperature being 16° C. Near the Shetlands a day or two later the sea-water temperature was 13.5° C., and immediately upon the western side of the islands the surface-water temperature was 12.94°. At this point, at a depth of 50 meters, there was a temperature of 9.89°; at 100 meters, 9.40°, and at 150 meters, 9.00°.

The *Rane* reached the Faroes on the 28th of July, and between the Faroes and Iceland temperatures of 9.89° at the surface, 9.78° at 50 meters depth, 8.30° at 100 meters, 7.35° at 200 meters, and 4.20° at 300 meters were recorded. On July 31, near Seydisfjord, Iceland, both the air and water temperatures were 5° C. At this point sea water at 50 meters depth was 4.32°.

It is interesting to note that only a few hours from Seydisfjord the sea water temperature rose from 5° to 9°. At 67° 43′ N. and 13° 33′ W. at 100 meters depth there was a temperature of 0°, the coldest recorded on the cruise. Over this cold water, from the surface down to 20 meters, the thermometer registered 7.35°. With the vessel near the western limit of the Gulf Stream, its course was directed eastward along the sixty-eighth degree of latitude, where the following increases in temperature were observed in the surface water between August 1 and 6. They were: 7.4°, 7.8°, 10.3°, 11.9°, 14.7°, and 16.0°. For the same days, but at a depth of 100 meters, these temperatures were recorded: 0°, 4°, 8°, 8°, 9°, and 10°. The warmest water was southwest of Lofoten.

On August 11 the *Rane* was at 72½° N. latitude and again at the western edge of the Gulf Stream. It was at this point that sails were resorted to after the engine trouble developed. From the records of the return trip, Doctor Sandstrom tells his readers that in the middle of the Skagerak, where about the 1st of September one may expect to find 4° C. water at a depth of 10 meters, the water on this date, 1930, had a remarkably high temperature, namely, 15.7° at the surface, 15.5° at 10 meters, and 9° at 60 meters. Doctor Sandstrom further remarks that this season the North Atlantic Gulf Stream is not only unusually warm in the north and west parts but also in the North Sea and Skagerak regions.

## METEOROLOGICAL PECULIARITIES OF THE YAKIMA VALLEY, WASHINGTON

By EDWIN H. JONES

[Weather Bureau, Yakima, Wash.]

A paper entitled "Meteorological Peculiarities of the Yakima Valley" might seem to be out of place in a convention dedicated to the fruit-frost and aviation phases of meteorology. It may be shown, however, that it is with these two activities of weather men that the weather abnormalities of the Yakima Valley are most directly connected.

At present the Yakima Valley project consists of 350,000 acres of irrigated land, most of which is highly cultivated. Its products are many, but fruit growing leads. In the average year there are shipped 48,650 carloads of products from the soil, 20,000 carloads of which are fruits. The total value of all these products is estimated at over $40,000,000 per year. As an isolated and landlocked district surrounded by mountains and desert, this agricultural community is confronted at the outset by two fundamental problems. First, the successful protection of its crops during growth against frost and the other hazards of climate, and then satisfactory transportation and communication with the outside world. The fruit-frost, spraying, packing, and shipping seasons provide activity for the meteorologist. In the successful development of aviation, with which the future of Yakima probably is bound up to the highest extent, an additional opening is offered.

The Yakima Valley is not "a valley," but a series of valleys or depressions in the general terrain. While all are drained by the Yakima River and its tributaries, there are no less than five distinct sections, each separated by sharp ridges of land rising from 800 to 1,500 feet above the valley floor, and with nothing more than narrow water gaps between for drainage both of water and air. The entire district slopes gently from an average elevation of about 1,600 feet above sea level at Ellensburg to 500 feet near Kennewick. The irrigable part is about 200 miles by road from end to end and perhaps 25 miles across at the widest place. Beginning at the north with the areas under irrigation and cultivation, there are: The Ellensburg or Kittitas, Selah, Naches, Upper Valley, and Lower Valley sections. Part of the Kennewick section is also drained by the Yakima River and is a part of the Yakima Valley. The Yakima Valley as a whole is closely adjacent to the Cascade Mountain system, the separating ridges being part of the foothills and the Cascade Mountain platform itself rising less than 25 miles directly to westward. It is this contiguity of the mountains, of course, which gives the Yakima Valley weather features peculiar unto itself.

Probably no person ever has attempted forecasts for the State of Washington without being agonized over the actions of the Yakima weather. The most common anomalies are temperatures that fall below the disaster point when other east-portion districts run comparatively safe, or occasionally, minimum temperatures that show a rise when other stations have no change. And there is the tendency to extreme dryness, even during the passage of a

considerable storm, then unexpectedly a few hundredths of an inch of precipitation to spoil an otherwise good forecast after the disturbance seemingly was all over. What is the exact nature of the terrain and what are the physical causes to produce such abnormalities? It is believed that the key to the answer may be summed up as follows: A high mountain barrier close to westward, but with a sizable gap to northwest for admittance of air currents. A gradually descending table-land from near this gap to southeastward, but with local air drainage considerably interfered with by numerous cross ridges. (The gap referred to is the comparatively low and narrow part of the Cascade Mountain platform in the vicinity of Snoqualmie Pass.)

With such a setting, the most pronounced adiabatic and radiational effects in the behavior of temperatures must be expected. It is the task of the forecaster, through continued application, to be able to estimate these effects. Variations in the maximum temperatures are uncommon and unimportant. In estimating minimum temperatures, the well-known hygrometric formula is used in connection with the evening weather map. The problem is to find the departure of the coming minimum above or below a median figure for dew point and humidity. Common types are: 1. Any pressure formation that will produce a north to south gradient, which, even weak, will cause steady, descending air movement at night with comparatively high temperature, while there may be no wind with lower temperatures in other districts. 2. The typical frost type is the weather map with indefinite gradient, or even strong southwest to northeast; then ideal conditions for uninterrupted radiation are provided, and the temperature fall is limited only by temperature of the dew point and time of sunrise. 3. But, let there be a south to north gradient, and a sluggish effect is noticeable, favorable for the development of cloud and higher temperatures. 4. With east to west gradient, cold air may be imported from the highlands of the Rockies and temperatures drop, even in the face, apparently, of a coming storm. Forecasting from the morning map, type and intensity which will produce the nighttime conditions have to be anticipated.

In the matter of precipitation, effect of the terrain seems to be even more pronounced. An increase in the annual total is noted as the Snoqualmie and Columbia River gaps are neared. The greater portion of the valley must get its precipitation through convection in a comparatively dry atmosphere or from admixture of the local atmosphere and a descending, drying current. As a rule, appreciable precipitation does not occur with a strong barometric gradient or even moderate general winds. The most common and favorable formation for precipitation is believed to be just after the center of the storm has begun to pass eastward, distance between the isobars widens out, and a certain amount of convection and mixing in a fairly moist atmosphere is possible.

One of the most remarkable peculiarities of the Yakima Valley weather is the variation of wind velocity with the seasons. The prevailing direction the year around of course, is northwest. During the winter months, December, January and February, when inland temperatures are low, there is no stimulation to the wind development of passing pressure formations. The absolute lack of local air drainage is most noticeable, the average hourly wind velocity at the Yakima Weather Bureau station being only two or three miles per hour. Smoke from local heating plants gathers over and in the city, conditions often rivalling those in the industrial centers of the east. With the coming of spring in March, however, the east to west temperature gradient is reversed. Each passing of a LOW trough is the signal for a rising northwest wind, with maximum generally in the afternoon and gradually dying down at night.

At intervals, winds develop in the spring season that are a temporary hazard to aviation. The pressure type is invariably an Alberta LOW with trough to southward. The difficulty in forecasting these winds any satisfactory time interval in advance is due to the variations in intensity of the different LOWS, a condition which is not always apparent on the weather map. Such winds often stir up dust storms of wide extent, interfering with visibility occasionally enough to obscure a landing field. The vertical limit of a dust storm, however, is rarely over 1,000 feet.

## THE PASSING OF THE MIRAGE LOCALLY

By A. A. JUSTICE

[Weather Bureau Office, Dodge City, Kans., July 27, 1930]

Mr. Robert M. Wright, in Dodge City, the Cowboy Capital, pioneer plainsman, freighter over the Old Santa Fe Trail, and for more than a half century an observer of conditions in Kansas, Colorado, and New Mexico, paints a very good word picture of the mirage as he saw it in the days before extensive settlements had been made in this region by the white man. He tells how the prairies were changed from dreary wastes into scenes of enchanting beauty, how cities, castles, and fortresses suddenly sprang up in a land where no man dwelt, and how lakes and rivers of sparkling water shimmered ahead of the thirsty traveler enticing him from the beaten trails, on and on to his death. He ends with the following:

> With the trail of the plow, followed by immigration and civilization, the wonderful mirage is a thing of the past. It is only now and then that one gets a glimpse of its beauties; its scenes of magnificence, far beyond any powers of description, I shall never see again.

That the mirage was of common occurrence during the period of settlement of the plains there can be little doubt. The frequency of its mention in the literature of the period is convincing evidence of that. And then, too, we have the corroborative testimony of the older living residents.

And what of it to-day? Is it still to be seen as often and on the same grand scale as it was 30, 40, or 50 years ago? Unfortunately our records are meager. The Weather Bureau has never taken very particular notice of the mirage nor compiled any data as to its occurrence, either in years past or to-day. It is evident, therefore, that we can not say definitely whether or not the mirage is passing as Mr. Wright claims.

But curiosity impels the question as to what other people think about it; what is the experience of some other old-timers. The mirage is an interesting phenomenon and it played a prominent part in the early history of the plains. It was something new and strange to the early settlers and they wrote back and told their friends whom they had left behind about it. So its fame spread.

Stories of how the mirage lured the thirsty travelers from the beaten trails are not figments of the imagination in all cases. First-hand knowledge of such experiences is related by living pioneers. But as a rule the

experiences of the newcomers to the prairies were not of such a tragic nature. An instance will illustrate.

Mr. Ham Bell, one of the oldest living residents of Dodge City and of southwestern Kansas, tells of his introduction to the mirage. "I came to Kansas," said he, "in 1872, landing one night in Ellsworth. The next morning I engaged a hack driver to take me to Great Bend, a distance of 45 miles. The driver charged me $45, a dollar a mile, for the trip, and he demanded payment in advance. The excuse for such an exorbitant price being the danger that would attend the crossing of a lake which could be seen in the distance and which he said his team would have to wade. The lake was only a mirage, but the rascally driver had my money before I found it out. The mirage is not seen to-day as it was then and people do not talk of it as they did in those days."

Commenting on the above, Mr. H. C. Bower, cooperative weather observer at Ellsworth, said: "The mirage is a rare occurrence in this part of the country nowadays. Not nearly so common as in years past."

A score or more of the older residents of Dodge City and southwestern Kansas were consulted by the writer. All were of one opinion—that the mirage is not now so common as it was in the early days, and that it does not occur on the same grand scale now as it once did.

Dr. O. H. Simpson, dentist, said:

> When I came to Dodge City in the early eighties, mirages were very common in this part of the country. In 1884 I drove over from Wichita with my bride and there were mirages all the way. I recall joking the wife about the rides which we would take on those "lakes." But it is quite different to-day. One can make the trip from Wichita here in the most favorable weather and perhaps never see a mirage, except the small ones in the level stretches of paved roads.

Dr. Claude E. McCarty, the first white child born in Dodge City, and, in the days of the Signal Corps, a civilian assistant at the Dodge City weather station, said:

> I am sure that there are not so many mirages to-day as there once was and they are not so big either. Why, it's been years and years since I have seen a mirage. Before the prairies were broken up one could not drive out in the country around Dodge City without seeing a mirage if the weather was favorable.

Others could be quoted without end. In talking with some people who have come to this country within the last 10 or 15 years some were found who had never seen a mirage and some of these people, maybe all of them, have automobiles and take occasional rides out into the country. The writer has been stationed here for the last 10 years and during that time has observed about three mirages. These were "loomings" on the southern horizon and were seen from the Weather Bureau building. They were insignificant, however, and perhaps would not have been noticed by the average person.

The country in the immediate vicinity of Dodge City is more or less broken and for that reason is not favorable for the appearance of the mirage. But away from the city a few miles there begin level stretches which extend long distances, and here the mirage might be seen on any warm sunny day provided other conditions were favorable, but evidently other conditions are not often favorable for it is rarely that the mirage is seen here.

Thirty years ago the writer spent a year on the Staked Plains of Texas. At that time and that region the mirage was exceedingly common. It was to be seen everywhere, if the sun shone and the weather was warm. It was very deceptive, for in many instances one could not tell for sure if he were looking at a real lake or a mirage. When the weather was favorable, the mirage usually made its first appearance around 9 o'clock in the morning and continued till about 4 in the afternoon. The "lakes" would usually appear to come as close as a half mile to the observer, varying with the observer's distance above the ground. By lowering the eyes to near the ground the mirage would appear to come within a hundred yards of the observer.

There were two distinct kinds of mirages. The "lakes" were by far the most common. These would be best when the sky was clear, but sometimes they could be seen even with an almost completely overcast sky. The wind did not prevent their formation, but would affect the illusory lake surface just as it would the surface of real water, ruffling it into small waves.

On very rare occasions, when conditions were just right, the manifestation technically known as "looming" would appear. This would develop on still, clear mornings when the ground surface had cooled off decidedly during the night, thus forming a layer of relatively cool, dense air next the surface of the ground. This mirage could as a rule be first seen with the advent of dawn. Distant landscapes would be elevated above the ordinary horizon, sometimes as much as three or more degrees. Distant objects, sometimes including towns and ranch houses, could be seen distinctly many miles away. Sometimes the elevated landscape would be right side up and sometimes upside down, such an effect being known as mirage.

After the sun had risen sufficiently to begin warming the surface of the ground there would appear a streak of sky along and above the ordinary horizon. The observer could then see a long streak of landscape, like a low-lying cloud, cut away from the earth by a gradually widening streak of skyline, the latter looking much like a streak of water. The streak of elevated landscape would grow narrower and narrower until at last it would disappear like a cloud in the sky.

Whether or not the mirages of the Staked Plains occur to-day as frequently and on the same scale as in years past remains a question, though the claim is made that the advent of the plow has had the same effect in that region as it has in others.

Mirage is caused by the refraction of light rays as they pass through layers of air of different densities. These layers of air of different densities are produced either by the excessive heating of the ground surface by the sun's rays in the daytime, which produces a layer of air next the ground of a higher temperature and of less density than the air layer immediately above; or by the excessive cooling of the ground surface by radiation at night which produces next the ground a layer of air of lower temperature and greater density than the air layer immediately above it.

In the first instance, rays of light, coming from the sky, strike the eye of the observer as coming from some point on the ground. This is because they are bent out of their course as they enter layers of air of different density. Thus a patch of sky is seen on the ground and is changed by the fancy of the observer into a lake of water.

In the second instance rays of light coming from objects beyond the horizon are bent in such a way as to strike the eye of the observer as coming from a point in the sky. Thus the observer sees the distant landscape up in the sky. This is the phenomenon known as "looming."

Mirages are commonly associated with water surfaces where a light wind from the land brings air of a different temperature from that over the water, also with deserts and sandy plains, for in such regions the ground heats up more quickly under the sun's rays and at night cools off more quickly than it does where vegetation partly or wholly covers the ground. It is obvious that the denser

the vegetable covering the smaller and slower will be the temperature changes of the ground surface and the less probability will there be of the appearance of the mirage. This is the basis of the argument that the turning of the prairies into farms has affected the frequency of the appearance of the mirage, for during the summer season, the time when mirages are most frequent, the crop covering is much more dense than that of the prairie grass covering. It is claimed that for a year or two following the great fires which occasionally swept the prairies in the early days, the mirage was unusually common. The fires burned the dry, dead vegetation which accumulated on the ground with the years and for several months thereafter there was more bare ground exposed to the sun's rays, etc., thus making the conditions more favorable for the formation of the mirage.

While such evidence as we have does not *prove* nor even *indicate* that the mirage has entirely disappeared from any extensive region, it does lend strong support to the statement of Mr. Wright that much of the beauty and glory of the mirage has vanished. That the phenomenon is occasionally seen around Dodge City and in other parts of southwest Kansas we have the positive statements of eye witnesses, many of them, that it is not seen nearly so often to-day as formerly is the positive assertion of many eye witnesses, with none, so far as the writer knows, claiming the contrary.

## SIMPLIFIED RAIN-INTENSITY FORMULAS

By C. E. GRUNSKY

[57 Post Street, San Francisco, Calif., October, 1930]

The account given by George V. Fish, United States Weather Bureau Office, Fla., in the MONTHLY WEATHER REVIEW, June, 1930, of a record rainfall at Miami from May 29 to June 2, inclusive, prompts the submission of formulas for the determination of probable maximum rain intensity during time periods of any length (less than a year) when the maximum rain rates during one or more storms of the extreme type are known.

It has been customary, heretofore, in such formulas to express time in minutes and the rain intensity in inches per hour. The formulas will take on a more convenient form if the duration of the rain be expressed in hours instead of in minutes.

No one has yet suggested a simple, single formula for rain intensity, satisfactorily applicable to such periods as a small fraction of an hour, an hour, a day, a week, a month, and an entire season. It is believed that the desired near approach to actual fact and a wide range of the time period can be obtained with the two formulas below noted. It is well known that for short periods of time the summation or mass curve of rainfall of maximum intensity has a shape closely approximating a parabola. The elements of a parabola, however, which will fit conditions of rain intensity for periods up to 24 or even 48 hours, indicate too much rain for materially longer periods. It is this fact which has led to the suggestion of two very simple formulas, one for rainstorms of relatively short and the other for storms of long duration. It is hoped that these formulas may prove helpful in determining from measured heavy rain rates the probable maximum rainfall in other than the observed time period.

Let $I_t$ represent the maximum average rate of rainfall, expressed in inches per hour, during any definite time period $t$.

Let $t$ represent the time, expressed in hours, during which rain falls with the average intensity $I$.

Let $C$ represent a coefficient which is to be ascertained for any locality from records of rainfall of extreme intensity.

Let $R$ represent the maximum rainfall in one hour, expressed in inches.

Let $R_t$ represent the total rainfall from the beginning of a rain storm of maximum intensity, during the $t$ hours of its duration.

The probable maximum intensity of rainfall during various periods of time can then be determined with the aid of the formulas:

$$I_t=\frac{C}{\sqrt{t}} \text{ when } t \text{ is less than 64 hours.} \quad (1)$$

$$I_t=\frac{2C}{\sqrt[3]{t^2}}=\frac{2C}{t^{2/3}} \text{ when } t \text{ is greater than 64 hours.} \quad (2)$$

These formulas in this simple form and their combination, which results in a continuous curved line, with a single negligible angle, will be found particularly helpful in approximating maximum rainfall for periods which do not differ too widely from the period of observed heavy rainfall which determines the value of the coefficient $C$.

It follows from (1) and (2) that—

$$R_t=\frac{C}{\sqrt{t}}t=C\sqrt{t} \text{ when } t \text{ is less than 64 hours.} \quad (3)$$

$$R_t=\frac{2C}{t^{2/3}}t=2C\sqrt[3]{t} \text{ when } t \text{ is greater than 64 hours.} \quad (4)$$

Moreover the coefficient $C$ will be equal to the maximum rain in one hour, because for $t=1$ it will be found from equations (1) and (3) that

$$I_1=C=R_1$$

*Rain at Miami, Fla., May 29 to June 2, 1930, Compared with Computed Maxima*

| Period | Observed rainfall | | Computed by formula | | Remarks |
|---|---|---|---|---|---|
| | Intensity per hour | Amount | Maximum intensity per hour | Maximum amount | |
| *Hours* | *Inches* | *Inches* | *Inches* | *Inches* | |
| 0.167 | | | 6.1 | 1.02 | 10 minutes. |
| .50 | | | 3.5 | 1.77 | 30 minutes. |
| 1 | 1.87 | 1.87 | 2.5 | 2.50 | |
| 2 | 1.54 | 2.07 | 1.77 | 3.54 | |
| 3 | | | 1.44 | 4.33 | |
| 4 | 1.10 | 4.39 | 1.25 | 5.00 | |
| 5 | .80 | 4.83 | 1.12 | 5.59 | By the formula. |
| 6 | | | 1.02 | 6.13 | $R_t=2.5\sqrt{t}$. |
| 12 | | | .94 | 8.65 | |
| 24 | .38 | 9.36 | .51 | 12.25 | |
| 44 | .375 | 16.49 | .378 | 16.60 | |
| 48 | | | .360 | 17.3 | |
| 72 | | | .286 | 20.6 | |
| 96 | | | .242 | 23.2 | |
| 120 | .161 | 19.28 | .205 | 24.6 | By the formula. |
| 240 | | | .108 | 26 | $R_t=5\sqrt[3]{t}$. |
| [1] 545 | .061 | [1] 33.16 | .075 | 41 | |
| 720 | | | .062 | 45 | |
| 1,440 | | | .0395 | 57 | Duration 1 month. |
| 8,640 | | | .0119 | 103 | 1 year. |

[1] This includes a period of 49 consecutive hours on May 27, 28, and 29 after the beginning of the storm, in which no rain fell.

Consequently when the maximum rainfall in one hour for any place has been ascertained, this can be taken as a first approximation of the value of $C$.

Thus for example, based on the 1 hour maximum record during the Miami storm, and no other approximation, the value $C=1.87$ would be indicated. (See MONTHLY WEATHER REVIEW, June, 1930, Vol. 58, p. 152.)

But, in this storm, as stated by Mr. Fish, on May 31 and June 1 the rainfall was 16.49 inches in 43 hours 56 minutes (43.93 hours). This was at an average rate or intensity of 0.375 inches per hour. Consequently for Miami—

$$I_{44}=\frac{C}{\sqrt{43.93}}=0.375$$

or

$$R_{44}=C\sqrt{43.93}=16.49$$

From either of these equations it follows that $C=2.48$.

As a check on this value it is to be noted that on May 31 in the same storm, the rainfall was 4.39 inches in 4 hours, or at the rate of 1.10 inches per hour. Therefore

$$R_4=C\sqrt{4}=4.39$$

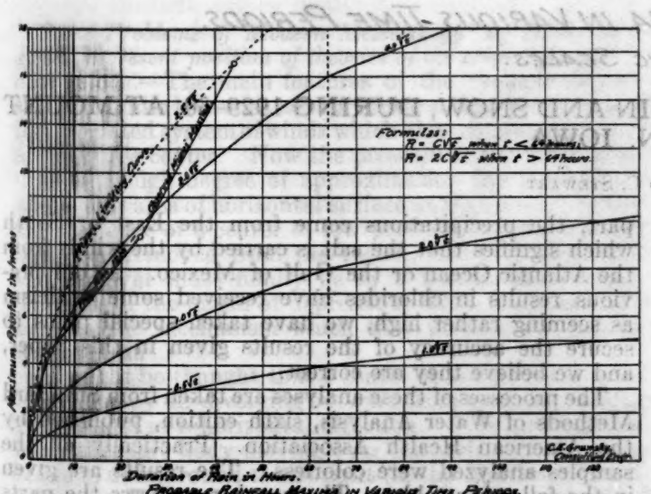
and $C=2.20$ a second or check determination.

It appears, then, that for Miami the value of $C$ should be taken at about 2.5. The formulas for maximum rain at Miami may now be written:

$$I_t=\frac{2.5}{\sqrt{t}} \text{ and } R_t=2.5\sqrt{t} \text{ when } t<64 \text{ hours}$$

$$I_t=\frac{5}{\sqrt[3]{t^2}} \text{ and } R_t=5\sqrt[3]{t} \text{ when } t>64 \text{ hours}$$

In the above table the measured rain during this May-June storm at Miami is compared with the computed probable maxima.




As shown in this table, the Miami storm may be accepted as having established a near record for the short-time periods of 1 hour, 2 hours, 4 hours, and a full day, as well as for the longer period of 44 hours.

It may be of interest to note that for Pacific coast (low-land conditions) the approximate range of the value of $C$ is 0.5 to 1.5.

For Middle West and Atlantic Slope conditions the approximate range of the value of $C$ is 2.0 to 4.0.

Probably the heaviest short-time rainfall ever measured was that on April 5, 1926, at Orpid's Camp, about 20 miles northeasterly from Los Angeles, Calif., on the slope of a high mountain range at an altitude of 4,480 feet where, early in the morning, observations were made with two recording rain gages about 4 feet apart. The one gage showed that in the one minute from 4:43 to 4:44 a. m. the rainfall was 1.03 inches. The other gage recorded 0.92 inch in one minute. In the 10 minutes from 4:40 to 4:50 a. m. the rainfall was 1.17 inches and from 2:40 to 3:40 a. m. the rainfall was 2.20 inches.

Taking the maximum rainfall of this storm at 1 inch in one minute, or 0.0167 of an hour, the value of $C$ is found to be (because $I$ for the one minute equals 60 inches).

$$C=60\sqrt{.0167}$$
$$C=7.8$$

At Campo near the south boundary of California, in the mountains easterly from San Diego, Calif., on August 12, 1891, there was a rainfall of 11.5 inches in 80 minutes. Here

$$I_t=8.65 \text{ and } t=1.33$$
$$C=8.65\sqrt{1.33}$$
$$=10.0 \text{ (in round number)}$$

By computing the probable maximum rate of rainfall for one minute with this value of $C$ it is found that

$I_{0.0167}=77$ inches per hour for one minute.

$R_{0.0167}=1.3$ inches, the probable maximum rainfall in the one minute of greatest intensity.

It therefore appears probable that even for the short-time period of one minute the rainfall at Campo in 1891 exceeded the measured rain in one minute at Orpid's Camp.

On the island of Oahu, Hawaii, at Dam No. 4 in the upper end of Nuuanu Valley in January, 1921, there was a rainfall of 20 inches in 24 hours. The caretaker at the dam, Mr. L. A. Moore, states that this rain fell in the 3 hours 7 to 10 a. m. The average rainfall was, therefore, about 6.67 inches per hour for a value of $t=3$. Consequently

$$I_3=6.67=\frac{C}{\sqrt{3}}$$

And $C=11.5$

Consequently

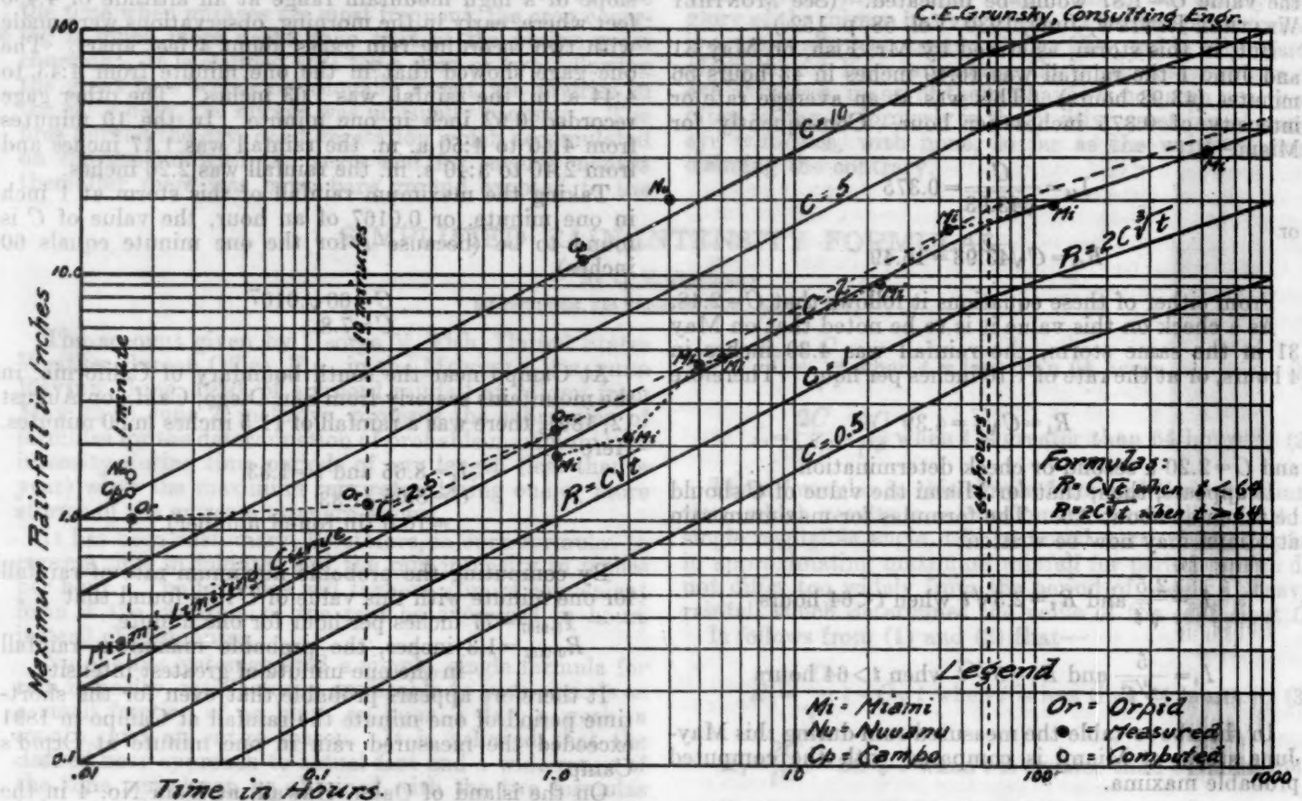
$$R_{0.0167}=11.5\sqrt{.0167}$$
$$=1.49 \text{ inches, the probable rain in the one minute of greatest rain intensity.}$$

This, too, was probably a storm which produced more rain in a single minute than the storm at Orpid's Camp.

It remains to be noted that such excessive rainfall is generally confined to small areas. Thus, for example, at a point 1½ miles from Campo during the great downpour above noted only 3 inches of rain fell. This was the record for the full duration of the storm.

Two diagrams have been prepared (figs. 1 and 2) to illustrate the shape of the curves which according to the suggested formulas would represent the limiting curves of maximum amounts of rain in various periods of time. In the one diagram natural scales have been used and in the other logarithmic scales.

The experienced meteorologist will know that values of the coefficient $C$ determined by actual measurement of very heavy rainfall during short periods of time, such as a few minutes or an hour or two, may not be applicable to long periods of time such as a week, month, or longer, and vice versa. The formulas are particularly helpful in approximating probable maximum amounts of rain over a considerable range of time in both directions from the time periods covered by actual observation.




PROBABLE RAINFALL MAXIMA IN VARIOUS TIME PERIODS.
LOGARITHMIC SCALES.

## ANALYSIS OF THE PRECIPITATIONS OF RAIN AND SNOW, DURING 1929–30, AT MOUNT VERNON, IOWA

By WILLARD C. STEWART

Under the direction of Dr. Nicholas Knight, of Cornell College, advanced students of chemistry have made analyses of the rains and snows that have been precipitated here for the past 20 years. The results of most of the work have been published in scientific journals.

The precipitations are collected in clean granite pans, 18 inches in diameter, away from trees and buildings and stored in glass-stoppered bottles. The village has no factories, and, exclusive of the college, has a population of about 1,700.

In estimating the chlorides, it has been found necessary to deduct 3.55 parts per million from the reading, to allow for the formation of the color. For the most part, the precipitations come from the East or South which signifies that the salt is carried by the winds from the Atlantic Ocean or the Gulf of Mexico. As our previous results in chlorides have received some criticism as seeming rather high, we have taken special pains to secure the accuracy of the results given in this paper, and we believe they are correct.

The processes of these analyses are taken from Standard Methods of Water Analysis, sixth edition, published by the American Health Association. Practically all the samples analyzed were colorless. The results are given in the following tables. The numbers express the parts of the various substances in a million parts of water.

TABLE 1.—*Rain and snow at Mount Vernon, Iowa*

| Number of sample | Date of precipitation | Amount | Rain or snow | Nitrates | Nitrites | Free ammonia | Albuminoid ammonia | Sulphates | Chlorine as chlorides |
|---|---|---|---|---|---|---|---|---|---|
| | 1929 | | | | | | | | |
| 1 | June 11 | 0.3 | Rain | 0.04 | 0.0014 | 0.056 | 0.4 | ..... | 14.20 |
| 2 | June 12 | 0.6 | do | 0.5 | 0.08 | 0.056 | Traces. | ..... | 17.75 |
| 3 | June 13 | 0.6 | do | 0.12 | ..... | 0.026 | 0.112 | ..... | 17.75 |
| 4 | June 30 | 0.8 | do | 0.4 | 0.003 | 0.8 | 0.16 | ..... | 17.75 |
| 5 | July 19 | 0.3 | do | 0.02 | 0.0014 | 0.112 | 0.16 | ..... | 21.35 |
| 6 | Sept. 16 | 0.25 | do | 0.8 | Traces. | ..... | 0.29 | ..... | 17.75 |
| 7 | Sept. 19 | 0.25 | do | 0.6 | 0.002 | 0.2 | ..... | ..... | 24.85 |
| 8 | Sept. 29 | 0.3 | do | 0.12 | ..... | 0.112 | 0.29 | 0.106 | ..... |
| 9 | Oct. 10 | 0.3 | do | 0.16 | 0.003 | ..... | 0.4 | ..... | 10.65 |
| 10 | Oct. 12 | 1.0 | do | 0.1 | 0.0014 | 0.26 | 0.112 | ..... | 24.85 |
| 11 | Oct. 20 | .75 | do | 0.24 | 0.0014 | 0.600 | 0.58 | 1.81 | 46.15 |
| 12 | Oct. 23 | 0.6 | do | 0.25 | ..... | 0.136 | 0.64 | ..... | 3.55 |
| 13 | Oct. 29 | 0.4 | do | 0.12 | 0.0029 | 0.78 | 0.64 | 0.789 | 11.65 |
| 14 | Oct. 31 | 0.4 | do | 0.4 | 0.0010 | 0.5 | 0.272 | 2.57 | 6.45 |
| 15 | Nov. 10 | 0.75 | do | 0.8 | 0.002 | 0.006 | 0.012 | 1.64 | 31.95 |
| 16 | Nov. 13 | 0.8 | do | 0.16 | 0.005 | 0.02 | 0.01 | ..... | 6.1 |
| 17 | Nov. 19 | 0.2 | do | 0.0014 | ..... | 0.015 | 0.07 | ..... | 10.65 |
| 18 | Nov. 27 | 0.12 | do | 0.0025 | ..... | 0.03 | 0.56 | ..... | 7.81 |
| 19 | Dec. 1 | 6 | Snow | 0.5 | 0.001 | 0.26 | 0.16 | ..... | 16.33 |
| 20 | Dec. 13 | .2 | Rain | 0.2 | 0.075 | 0.2 | 1.4 | ..... | 2.13 |
| 21 | Jan. 2 | [1]3 | Snow | 0.16 | 0.004 | 0.72 | 0.32 | 0.493 | ..... |
| 22 | Jan. 7 | 4 | do | 0.6 | Traces. | 0.78 | 0.16 | 0.647 | 24.8 |
| 23 | Jan. 9 | 6 | do | 0.02 | 0.002 | 0.6 | 0.29 | ..... | 7.81 |
| 24 | Jan. 13 | 3 | do | 0.6 | Traces. | 0.32 | 0.16 | ..... | 21.3 |
| 25 | Jan. 14 | 6 | do | 0.4 | Traces. | 0.36 | 0.16 | 0.281 | 10.36 |
| 26 | Jan. 17 | 2 | do | 0.5 | Traces. | 0.08 | 0.25 | 0.044 | 17.4 |
| 27 | Jan. 21 | 2 | do | 0.3 | Traces. | 0.36 | 0.36 | ..... | 4.97 |
| 28 | Feb. 16 | 2 | do | 0.4 | Traces. | 0.45 | 0.9 | 0.233 | 31.95 |
| 29 | Feb. 24 | 0.5 | Rain | 0.4 | 0.0001 | 0.36 | 0.48 | 0.013 | 24.85 |
| 30 | Feb. 25 | 0.6 | do | 0.12 | Traces. | 0.16 | 0.112 | 0.123 | 42.6 |
| 31 | do | 0.1 | do | ..... | 0.0007 | 0.36 | 0.32 | ..... | 3.55 |
| 32 | Feb. 28 | 0.18 | do | 0.03 | 0.0025 | 0.36 | 0.36 | 0.219 | 2.6 |
| 33 | Mar. 17 | 0.3 | do | 0.08 | 0.0015 | 0.72 | 0.8 | 0.815 | 24.85 |
| 34 | Mar. 18 | 0.3 | do | 0.06 | 0.0002 | 0.16 | 0.36 | 0.104 | 10.6 |
| 35 | Apr. 11 | 0.4 | do | 0.16 | 0.0004 | 0.36 | 0.72 | 0.247 | 17.45 |
| 36 | Apr. 13 | 0.25 | do | 0.8 | 0.0001 | 0.112 | 0.16 | 0.195 | 10.65 |
| 37 | Apr. 15 | 1 | do | 0.5 | 0.0003 | 0.32 | 0.36 | 0.096 | 21.3 |
| 38 | Apr. 16 | 0.5 | do | 0.6 | 0.0001 | 0.16 | 0.32 | 0.123 | 28.4 |
| 39 | Apr. 20 | 1.1 | do | 0.16 | 0.0001 | 0.112 | 0.64 | ..... | 23.7 |
| 40 | Apr. 27 | 0.2 | do | 0.1 | 0.002 | 0.136 | 0.36 | ..... | 10.65 |
| 41 | Apr. 29 | 0.16 | do | 0.6 | 0.0025 | 0.32 | 0.4 | ..... | 7.1 |
| 42 | May 1 | 0.4 | do | 0.12 | 0.0025 | 0.01 | 0.002 | ..... | 2.75 |
| 43 | May 2 | 0.6 | do | 0.05 | 0.0014 | 0.01 | 0.001 | ..... | ..... |
| 44 | May 4 | 0.85 | do | 0.07 | 0.0025 | ..... | ..... | ..... | 31.95 |
| 45 | May 7 | 0.1 | do | 0.1 | Traces. | 0.01 | 0.01 | 0.0042 | 17.75 |
| 46 | May 11 | 0.5 | do | 0.9 | 0.0025 | ..... | ..... | ..... | 10.6 |
| 47 | May 16 | 0.25 | do | 0.14 | 0.02 | ..... | ..... | ..... | 3.55 |
| 48 | May 23 | 1.2 | do | 0.0016 | 0.0007 | ..... | ..... | ..... | 31.95 |

[1] Inches.

TABLE 2.—*Data from Table 1 converted to pounds per acre*

[1 inch rain over 1 acre=226,875.0 pounds. 12 inches snow=1 inch rain]

| Number | Nitrates | Nitrites | Free ammonia | Albuminoid ammonia | Sulphates | Chlorides |
|---|---|---|---|---|---|---|
| 1 | 2.72 | 0.91 | 3.8 | 0.27 | ..... | 0.9664 |
| 2 | 6.80 | 10.8 | 7.6 | Traces. | ..... | 2.4162 |
| 3 | 16.33 | ..... | 35.3 | 0.05 | ..... | 2.4162 |
| 4 | 7.26 | 5.4 | 14.5 | 2.89 | ..... | 3.0202 |
| 5 | 1.36 | 0.91 | 7.6 | 10.8 | ..... | 1.4531 |
| 6 | 4.53 | ..... | ..... | 1.64 | ..... | 1.0067 |
| 7 | 3.4 | 1.13 | 11.3 | ..... | ..... | 1.4094 |
| 8 | 8.16 | ..... | 7.6 | 5.9 | 0.0721 | ..... |
| 9 | 10.89 | 2.0 | ..... | 0.2 | ..... | 0.7248 |
| 10 | 22.68 | 3.17 | 58.9 | 2.54 | ..... | 5.6378 |
| 11 | 40.83 | 2.26 | 102.0 | 9.86 | 0.3079 | 7.8527 |
| 12 | 34.03 | ..... | 18.5 | 8.71 | ..... | 0.4832 |
| 13 | 10.89 | 16.33 | 70.7 | 5.8 | 0.0559 | 1.0572 |
| 14 | 3.63 | 0.9 | 45.3 | 2.46 | 0.4373 | 0.5853 |
| 15 | 13.61 | 0.34 | 1.0 | 0.81 | 0.2976 | 5.4364 |
| 16 | 29.04 | 0.83 | 3.5 | 0.18 | ..... | 1.1071 |
| 17 | 0.00006 | ..... | 0.6 | 0.3 | ..... | 0.4832 |
| 18 | 0.00006 | ..... | 0.8 | 0.13 | ..... | 0.2126 |
| 19 | 56.71 | 1.13 | 9.4 | 1.81 | ..... | 1.8524 |
| 20 | 9.07 | 34.03 | 1.36 | 4.70 | ..... | 0.0952 |
| 21 | 4.07 | 2.26 | 40.83 | 1.81 | 0.0279 | ..... |
| 22 | 4.53 | ..... | 68.98 | 1.2 | 0.0489 | ..... |
| 23 | 22.68 | 2.26 | 68.6 | 3.28 | ..... | 0.8359 |
| 24 | 34.03 | ..... | 18.15 | 0.9 | ..... | 1.2081 |
| 25 | 45.37 | ..... | 40.83 | 1.81 | 0.0208 | 1.1752 |
| 26 | 18.70 | ..... | 3.02 | 0.94 | 0.0019 | 0.7731 |
| 27 | 1.13 | ..... | 13.61 | 1.34 | ..... | 1.8418 |
| 28 | 1.51 | ..... | 204.18 | 3.40 | 0.0105 | 14.4972 |
| 29 | 1.51 | 1.23 | 40.83 | 5.44 | 0.0014 | 1.1275 |
| 30 | 4.53 | ..... | 3.02 | 7.52 | 0.0167 | 5.7988 |
| 31 | ..... | 9.52 | 49.0 | 0.72 | ..... | 0.8050 |
| 32 | 0.122 | 10.2 | 15.01 | 1.46 | 0.0089 | 0.7637 |
| 33 | 10.89 | 10.2 | 49.0 | 0.54 | 0.0579 | 1.5637 |
| 34 | 8.16 | 1.36 | 10.89 | 5.44 | 0.0070 | 0.7214 |
| 35 | 14.51 | 3.63 | 32.67 | 6.53 | 0.0224 | 0.5832 |
| 36 | 4.53 | 0.567 | 6.35 | 0.9 | 0.0110 | 0.9664 |
| 37 | 11.34 | 6.8 | 95.28 | 8.16 | 0.0217 | 4.8324 |
| 38 | 6.80 | 1.13 | 18.15 | 3.63 | 0.0189 | 3.2216 |
| 39 | 39.91 | 2.52 | 27.95 | 15.94 | ..... | 5.7574 |
| 40 | 4.51 | 9.07 | 6.17 | 1.63 | ..... | 4.8032 |
| 41 | 2.17 | 9.07 | 11.61 | 0.14 | ..... | 0.1006 |
| 42 | 7.54 | 22.68 | 0.9 | 0.045 | ..... | 0.2495 |
| 43 | 2.71 | 19.45 | 1.35 | 0.013 | ..... | ..... |
| 44 | 2.57 | 48.20 | ..... | ..... | ..... | 2.5063 |
| 45 | 2.26 | ..... | 0.22 | 0.02 | 0.3667 | 0.4027 |
| 46 | 12.60 | 45.37 | ..... | ..... | ..... | 1.0701 |
| 47 | 3.97 | 278.43 | ..... | ..... | ..... | 1.5658 |
| 48 | 17.01 | 3.53 | ..... | ..... | ..... | 0.781 |

## NOTES, ABSTRACTS, AND REVIEWS

*Some Problems of Modern Meteorology*[1] *by D. Brunt—I. The present position of theories of the origin of cyclonic depressions.*—The main features of the cyclonic depression of middle latitudes are its center of low pressure and its associated system of winds which blow counterclockwise around this center. Now the pressure at any level measures to a high degree of approximation the mass of air above unit area of horizontal surface at that level. Hence the existence of a center of low pressure denotes that air has been removed from the region, and it is clear that the removal must finally be in a horizontal direction. Theories of the origin of depressions differ fundamentally only in the mechanism which they propose for this removal of air.

It might be thought that a center of low pressure could be formed by air diverging outward from a center, moving everywhere in a horizontal direction. It is known, however, that any body moving over the surface of the earth tends to swing round to the right (in the Northern Hemisphere). Hence the divergence of air from a point would generate a clockwise rotation of the air, and would produce a system of winds opposite to those in the cyclone. The suggestion of accounting for a depression by divergence from the central area is therefore ruled out.

The only alternative is convergence towards the central region, which by a similar line of argument is seen to produce a counterclockwise system of winds. The excess of air which would otherwise accumulate in the central region must be removed by vertical motion initially. But since the removal of the superfluous air to a higher level does not in itself produce a decrease of surface pressure, we must further postulate some mechanism capable of removing the superfluous air horizontally. There appears to be only one possible mechanism, an upper current moving with a different velocity and possibly in a different direction, from the currents of lower levels. We are thus led from the general nature of cyclonic depressions to postulate two conditions as necessary for their formation—firstly, an ascending current of air in the lower troposphere, strictly limited in horizontal extent, and secondly, an upper current differing in speed or direction or both, from the currents in the lower troposphere. If the upper current has the same direction as the currents of the lower troposphere, it will be constantly moving forward in advance of the depression, and any clouds formed within it will appear to move outward from the center in the line of advance. These clouds would herald the approach of the depression. If on the other hand the upper current is in a different direction from the currents of the lower troposphere, any clouds formed in the upper current will fail to indicate the line of advance of the

[1] Under this title it is proposed to publish a series of brief articles by various authors discussing some of the unsolved problems of meteorology. They will aim not at advocating new theories, but at stating the difficulties involved in existing theories. (Reprinted from Quarterly Jour. Roy. Met. Soc., July, 1930, pp. 345-350.

depression. Much has been written of the use of cirrus clouds as prognostics of the line of advance of a depression, but the net result appears to be that cirrus movement may be anywhere within the two front quadrants of the depression (see Pick and Bowering, Q. J. R. Meteor. Soc., January, 1929, p. 71). Thus the observed movements of cirrus indicate that the upper current is usually oriented at any angle up to 90° with the direction of the lower currents. The fact that the cirrus movement is seldom, if ever, opposite in direction to the motion of the lower levels agrees with the idea that the prevailing air movement in middle latitudes is in general from west to east.

We are, therefore, in a position to assume the existence of a strong upper current at the cirrus level as a feature of all depressions, and as such a current is a necessary feature of the formation of depressions on any theory, the only difference that remains between different theories consists in the mechanism which they propose to account for the vertical removal of air in the lower layers of the troposphere.

The two main theories available to account for the vertical removal of air are the "local heating" theory and the "polar-front" theory. The first of these assumes that the air over a restricted region is heated to a higher temperature than its surroundings, or is heated from below by contact with heated ground or warmer sea until it becomes unstable. The heated air may then be capable of rising to considerable heights. The effect of high temperature may be increased by high humidity, since damp air is lighter than warm air at the same pressure and temperature. If the lapse rate is less than the dry adiabatic but greater than the saturated adiabatic, and any surface air which is saturated and at a higher temperature than its environment begins to ascend, it will become increasingly warmer than its environment with increasing height. The motive power is the lowering of density of a portion of the air below that of its environment, and it is probable that the effect of water vapor on the rate of decrease with height of the temperature of the ascending air is an important factor in the convection. The phenomenon of ascent is not as simple as we have supposed above. The ascending air can not remain intact during its ascent. Turbulence will be set up at its boundary, causing some mixing with the environment, but the effect of mixing is to share the defect of density between the total mass which mixes, and the whole mixture will be lighter than its environment, and therefore capable of ascent. The mixing here described is a necessary feature of the formation of a cyclonic depression by convection. The system of winds is regarded as an effect of the horizontal convergence of air to take the place of air removed by convection, and the extension of the system of winds to considerable heights demands the removal of air from all levels up to these heights, and except in the lowest layers the necessary removal is brought about by the effect of mixing of the ascending air with some of its immediate surroundings, a process to which Sir Napier Shaw gave the name of "eviction."

Water vapor is regarded as an essential factor in the theory as stated above to the extent that the ascending air is assumed to be saturated either initially or at an early stage in its ascent. In completely dry air the same phenomena would demand enormous local differences of temperature. The mean lapse rate in the troposphere is about 0.6° C. per 100 meters, the dry adiabatic being 1° C. per 100 meters. Thus ascending dry air would approach the temperature of its environment at the rate of 0.4° C. per 100 meters, or 4° C. per kilometers and ascent up to 5 kilometers would only be possible for air which initially had a temperature 20° C. higher than the normal surface temperature of its environment.

If, however, we may assume the initial lapse rate to lie between the dry and saturated adiabatics, then a relatively small increase of temperature in the lowest layer will enable damp surface air to rise to considerable heights; or instability in a relatively shallow layer near the surface will act as a trigger to set in motion convection capable of extending to the top of the troposphere. And it must be noted that marked instability when produced by surface heating is limited to a relatively shallow surface layer. It is for this reason that emphasis is laid on the function of water vapor in the process, and on the effects of mixing of the ascending air with its environment during the ascent.

The "local-heating" theory which we have just outlined thus reduces itself to finding a physical cause capable of producing instability in the surface layer, over a sufficient area. The most obvious cause to consider is the direct effect of solar radiation in heating the surface of the earth. But the direct effect of solar radiation on the surface of the sea is very slight, and produces only a small diurnal variation of temperature, with a total range of about 1° F. Moreover, most of the cyclonic depressions of middle latitudes originate over the ocean. We can not, therefore, assume that direct solar radiation is capable of producing over the ocean the intense local heating of the air sufficient to give rise to depressions.

There is, however, a plausible alternative to this. Air originating in high latitudes, and moving to low latitudes, will be heated from below as it passes over progressively warmer land or ocean, until a stage is reached at which marked instability occurs in the lowest layers. The surface air will be at or near saturation, and when convection starts it can proceed to very great heights. We might therefore expect that depressions should form in cold polar currents. This is borne out by observation, since it is not infrequently noted that depressions are formed in cold polar currents. These are the only depressions formed over the ocean whose origin can be definitely ascribed to instability.

The first clear discussions of the convection or local-heating theory outlined above will be found in Espy's Philosophy of Storms. Espy was also the first to emphasize the importance of water vapor in the atmosphere. The same ideas underlie what are known as "revolving-fluid" theories, as discussed recently by Shaw,[2] Brunt,[3] and others.

The main alternative to the local-heating theory is the polar-front theory, developed during the last 15 years or so by the Norwegians. This theory in a more or less definite form can be traced in earlier writers, but it was left to V. and J. Bjerknes and their colleagues to give it a definite form. Dove[4] developed in some detail the idea that a cyclone could be regarded as a region of opposition between warm and cold currents, and later writers supported this view. Bigelow[5] pointed out that on the whole cyclones could not be regarded as having warm centers or cold centers, but that the phenomena could be more accurately described by saying that the centers of cyclones usually occurred along the

[2] Shaw: Revolving fluid in the atmosphere. *London, Proc. R. Soc.*, A, 94, 1917, p. 33; also *London, Meteorological Office, Geophysical Memoirs*, No. 12.
[3] Brunt: Revolving fluid on a rotating earth. *London, Proc. R. Soc.*, A, 99, 1921, p. 397; *ibid.*, 105, 1924, p. 70.
[4] *Vide* Sprung: Lehrbuch der Meteorologie, Hamburg, 1885.
[5] *Washington, Monthly Weather Review*, 1902, p. 251.

lines separating warm and cold currents. Again Shaw and Lempfert[6] showed that the rain which fell in a cyclone could be explained by the forced convection due to the convergence of air, or by the ascent of warm air over cold air. V. Bjerknes[7] combined Shaw and Lempfert's picture of the cyclone with the ideas of Helmholtz.[8] The latter had shown that two currents of air of different temperatures and different velocities could flow side by side separated by a surface of discontinuity, the arrangement being stable. Bjerknes suggested that the cyclone should be visualized as a wave in the surface of separation, between a cold easterly or "polar" current, and a warm westerly or "equatorial" current. The surface of separation, or more frequently its intersection with sea level, is known as the "polar front." The wave increases in amplitude, and a cyclone sometimes forms at the northern crest of the wave The theory is very strongly reminiscent of Emden's[9] theory of the origin of sunspots.

In discussing this theory it is necessary to draw a clear distinction between the theoretical discussions of V. Bjerknes and the methods of analysis of synoptic charts developed by his son, J. Bjerknes.[10] The latter pictures the development of a depression as starting with a straight line separating the cold easterly current from the warm westerly current. The first step is a bulge of the warm air into the cold air, and as the bulge increases, a well-marked center of low pressure develops at the tip of the bulge. The warm tongue is compressed by the cold air and eventually all the warm air is pushed up from the ground. From this stage onward the depression decreases in intensity, and its motion of translation dies away.

We are not here concerned to describe the association of weather with the different parts of the system described by J. Bjerknes. The reader will find full descriptions of these in the original papers. The practical use of these ideas has been elaborated by the author in a masterly way. Moreover, there is no question that in a large number of cyclones of middle latitudes the development of the cyclone is associated with developments of the polar front in the precise manner described by J. Bjerknes.

The difficulty lies not so much in confirming the association of cold fronts with cyclones as in obtaining a clear idea of the physical principles underlying the association. In the first place the polar-front surface is only inclined at a small angle of 1° or less to the horizontal, and in any gravitational wave formed in this surface the motions should be predominantly vertical. V. Bjerknes suggests that the effect of the earth's rotation will be to increase the extent of the horizontal components of motion, so that they become enormously greater instead of much less than the vertical motions, but this process is not obvious. There is the further difficulty that the manner in which the warm air is caused to ascend over the cold air is by no means clear. Helmholtz suggested in one of his early papers that the warm and cold air would not in practice be separated by a sharp surface of discontinuity, but by a layer formed by the mixing of cold and warm air, and he further suggested that the initial ascent takes place in the layer of mixing.

The outstanding physical difference between the polar-front theory and the local-heating theory is to be found in the cause of the ascent of air. In the one case the ascent is apparently largely due to dynamical causes, while in the other it is due to thermal causes. But this distinction must not be taken too literally, since atmospheric phenomena are seldom to be interpreted as purely dynamical or purely thermal. Again Helmholtz showed that the cold and warm currents are in equilibrium when separated by a sharp surface of discontinuity, and it is not clear why the warm air begins to ascend up the slope of the wedge of cold air. Oscillations in the surface of separation should rapidly die out. It is, of course, possible that even in depressions formed at a polar front the initial stages are produced by thermal causes. But when the motion of cold and warm currents is geostrophic, there is no tendency for the warm air to climb over the cold air, as has been emphasized by Brunt and Douglas.[11] Helmholtz also showed that the waves formed in the surface of discontinuity should have wave lengths of the order of 1 kilometer rather than of the 1,000 kilometers which would be more appropriate in the case of cyclones.

To summarize our present view, we may say briefly that while it is undeniable that depressions frequently form at surfaces of discontinuity, and that the weather within them can be explained by the interaction of warm and cold currents at the polar front, yet it is not clear what causes the growth of the depression initially. Nor must it be overlooked that frequently fronts occur at which no depression subsequently forms. It is not even clear that the condition laid down earlier in the present article, that there must be an upper current differing from the current in the lower troposphere, is itself sufficient to determine whether a depression shall form or not. But this particular question has never been investigated in full detail.

Exner[12] and others of the Austrian school of meteorologists have regarded cyclones as formed, not at a continuous polar front, but at the edge of a discontinuous outburst of cold air. The cold air bursting southward as a tongue projected into the warm current cuts off the supply of air from the region to its left, causing a diminution of pressure at that point. At the same time the warm air is dammed up behind the cold tongue (i. e., to its right), causing an anticyclone there. The theoretical discussion of these subjects leaves it uncertain whether the processes suggested would produce the changes of pressure which are actually observed in the atmosphere. Exner's views on this subject are to be found mainly in his textbook, *Dynamische Meteorologie*, but a very complete bibliography of Austrian papers on this and allied subjects up to the end of 1922 has been given by Ficker.[13]

Whatever view we may adopt concerning the genesis of cyclones, we find that the fundamental cause is always to be ascribed to the direct or indirect effect of horizontal differences of temperature over the earth's surface. Since the horizontal differences of temperature are greatest in winter, cyclones should be more frequent and more intense in winter than in summer. The strength of the currents in the atmosphere are proportional to the horizontal temperature gradients.

[6] The Life History of Surface Air Currents, London, 1906.
[7] V. Bjerknes: The dynamics of the circular vortex, etc. *Geofysiske Publikationer*, 2, No. 4. The structure of the atmosphere when rain is falling. *Q. J. R. Meteor. Soc.*, 46, 1920, p. 119.
[8] *Wien, SitzBer. Akad. Wiss.*, 1888, p. 647; 1889, p. 761. These papers are reproduced in Wissenschaftliche Abhandlungen of Helmholtz and are given in Abbe's Collected Translations, Series II.
[9] Emden: Gaskugeln, 1st edition Berlin, 1907, Chapter XVIII.
[10] J. Bjerknes: On the structure of moving cyclones. *Geofysiske Publikationer*, 1, No. 2.
J. Bjerknes and H. Solberg: Meteorological conditions for the formation of rain; *ibid.*, 2, No. 3.
J. Bjerknes and H. Solberg: Life cycle of cyclones and the polar-front theory of atmospheric circulations, *ibid.*, 3, No. 1.
J. Bjerknes: Diagnostic and prognostic applications of mountain observations, *ibid.*, 3, No. 6.
Bergeron and Swoboda: Wellen und Wirbel an einer quasistationären Grenzfläche über Europa, *Veröff Geophys. Inst. Univ., Leipzig*, 3, No. 2. This paper gives a very complete summary of the views of the Norwegian school.
A. Refsdal: Der feuchtlabile Niederschlag, *Geofysiske Publikationer*, 5, No.12.
[11] Brunt and Douglas: *Mem. R. Meteor. Soc.*, 3, No. 22.
[12] Exner: Dynamische Meteorologie, 2d edition, Chapter XII.
[13] Ficker: *Met. Zs.*, March, 1923.

The ideas described above all ascribe to conditions in the lower atmosphere the predominating rôle. Exner [14] on the other hand has suggested that the major changes of pressure are brought about by advection, or horizontal movement of air masses of different temperatures. C. K. M. Douglas [15] has also suggested in recent papers that the advection of low pressure at high levels may play an important rôle in the formation of cyclones, but the physical processes involved in this have not yet been thoroughly discussed.

Kobayasi [16] has shown that if a column of revolving fluid draws in air of different temperatures from different sides it may produce lines of discontinuity of temperature at the surface.

Any theory which shall provide a full explanation of the processes in a cyclone must explain the lowering of the stratosphere above it, and the relative cold in the troposphere, and relative warmth in the stratosphere in a cyclonic region. The statistical data bearing on this aspect of the subject have been given by the late Mr. W. H. Dines.[17]

*Exceptionally severe snowstorm of October 18–19, 1930, near Buffalo, N. Y. By J. H. Spencer, Weather Bureau, Buffalo, N. Y.*—The very heavy and wet snowfall of Saturday and Sunday, October 18 and 19, was south from Buffalo to Erie and beyond, where one of the worst storms of record occurred, amounts ranging from 6 inches to 3 or 4 feet falling over a great area, but worse perhaps in the Hamburg-Angola section. The temperature was near the freezing point. The Lake Shore and other highways of that section became impassible, and hundreds of motorists were stranded in their cars or near-by farmhouses and taverns some for 24 hours or more.

Apple orchards were heavy with fruit, and the added weight of the snow broke down many trees. Many shade trees were also ruined. Telephone and power lines were down in many sections, and rail, bus, and steamship lines were hampered or interrupted. The roofs of some buildings collapsed because of the weight of the snow. A day or two before the storm summerlike conditions prevailed and late fall flowers were in bloom, even roses.

The great fall of snow near the south shore of Lake Erie was caused by abnormally cold weather and moisture-laden west winds off the lake, occurring at a time when a pronounced southwest storm area covered the entire lake region and districts to the northward. This disturbance remained nearly stationary over the Great Lakes for more than three days, causing one snow period after another.

Buffalo, except the south portion, escaped the storm because west winds that blow over central and northern sections of the city do not come off the lake. Snowfall on Sunday, October 19, in the vicinity of Church and Franklin Streets, was nearly 2 inches; in the Delaware Park section it was less than one-half inch; and in South Buffalo 6 inches or more. Little snow fell at the Buffalo airport. From Buffalo north to Niagara Falls, northeast to Lockport, and east to Williamsville and beyond there was also little or no snow. At the time the snowfall at Angola was deepest, and highways impassible, there was no snow whatever 3 miles away on the shore of the lake, where the grass was green and flowers blooming, but with a misty rain. Dunkirk and Hamburg were among the cities without electric lights and power until the lines were restored after the storm.

Among the losses reported by the press in western New York were the following: A building at the Angola airport caved in; also the roof of the Angola Hotel, resulting in damage of about $3,000. At Orchard Park the roof of the Acme Veneering Co. collapsed, causing damage around $5,000. Thousands of dollars in damage to fruit trees resulted in the vicinity of Orchard Park and other sections. Several roofs caved in at Dunkirk, among them the Famous Store, which reported a loss of $15,000. The roof of Floral Hall at the county fair grounds, Dunkirk, also caved in. Damage to shade trees and shrubbery, South Park, Buffalo, was estimated at $50,000.

The following are the amounts of snowfall reported to this office: Angola, 42 inches; Arcade, 7; Belfast, 2; Belmont, none; Bliss, 8; Boston, 30; Cherry Creek, 1; Dansville, 2; Dayton, 15; Dunkirk, 36; East Aurora, 37; Eden, 48; Ellicottville, 3; Franklinville, 3; Geneseo, 1; Gowanda, 5; Hamburg, 33; Hamlet, 5; Holland, 24; Lancaster, 15; Mount Morris, 3; New Albion, 6; Orchard Park, 42; Randolph, 4; Sinclairville, 5; Silver Creek, 36; Springville, 6; Strykerville, 36; Warsaw, 10; and West Valley, 4.

*A new rainfall map of the State of Washington* [18] *by Dr. O. W. Freeman, State Normal, Cheney, Wash.* [*author's abstract*].—Previous rainfall maps of Washington have been so generalized, especially in eastern Washington, that they failed to show as close a relationship to the relief and to the vegetation of the region as was desirable.

Isohyets drawn on the present map used all the records available in the State for mean annual rainfall. Stations having records for only a few years were compared with Spokane and Walla Walla in eastern Washington and Seattle in western Washington as standards since these places have long continuous records, and such corrections as were needed were made and the adjusted results used in drawing the isohyets. In places where no records were available personal observations by the author of the vegetation and relief were used in the location of critical isohyets.

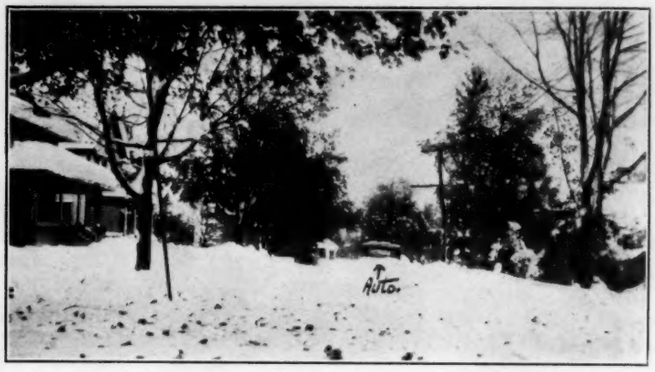
In western Washington 20, 30, 40, 60, 80, 100, and 120 inch isohyets were drawn. In eastern Washington 8, 10, 12, 15, and 25 inch isohyets were added. This was found necessary because the usual jump from 10 to 20 inch annual rainfall, which is an increase of 100 per cent is too much to show the proper relationship between farm crops or natural vegetation and the rainfall.

The rainfall of Washington is principally affected by the Pacific Ocean, the direction of the prevailing winds, the relief of the land, and the course of the cyclones. There are three zones of heavy rainfall crossing the State north and south. These correspond to the Coast Range, Cascades, and Highlands of eastern Washington. To leeward of the Coast Range the rainfall declines in the Puget Sound lowland, especially in the rain shadow of the Olympics where it is under 20 inches.

In eastern Washington the 15-inch isohyet corresponds to the limit of growth toward the dry lands of the yellow pine (pinus ponderosa). The 12-inch isohyet marks the limit of the bunch grass and the preponderance of the sagebrush begins. Above the 12-inch isohyet wheat raising is generally successful. Between 10 and 12 inches the best farmers can still succeed in most years, although crop damage from drought is common. From 8 to 10 inches is quite definitely border-line farming and failures probably outnumber successes. Below 8 inches annually wheat raising is rarely tried any more and never

[14] Exner: Dynamische Meteorologie, Chapters XI and XII.
[15] C. K. M. Douglas: *Q. J. R. Meteor. Soc.*, 54, 1928, pp. 19–25; 55, 1929, pp. 123–151.
[16] Kobayasi: *Q. J. R. Meteor. Soc.*, 49, 1923, p. 177.
[17] W. H. Dines: The characteristics of the free atmosphere; *London, Meteorological Office, Geophysical Memoirs*, No. 13.

[18] Presented at Eugene, Oreg., meeting American Meteorological Society, June, 1930.



Heavy snowfall (42 inches) at Angola, N. Y., on October 17–18, 1930

UNIV. OF MICH.

was permanently successful. Under these conditions irrigation must be used if crops are raised. Fortunately the heavy snows of winter in the mountains in most years supply an abundance of irrigation water to fruitful valleys that lie in the rain shadow of the highlands.

*M. A. Giblett, 1894–1930.*—The untimely death of M. A. Giblett in the crash of the *R–101* on October 5 brought to a close a life that was not only full of accomplishment but also one that gave promise of a much enlarged sphere of usefulness in the years that are to come.

Giblett, in company of J. Bjerknes, paid a short visit to the central office of the Weather Bureau in the late summer of 1924. Together they made an analysis of the working charts of the forecast division of the bureau and contributed a paper bearing the title An Analysis of a Retrograde Depression in the Eastern United States, published in this REVIEW 52:521–27. While at the Weather Bureau he endeared himself to the members of the staff by his intense enthusiasm in his chosen work and his charming personality. The sympathy of his friends on this side of the Atlantic goes out to the family and associates of the deceased.—*A. J. H.*

*Sunspots and pressure distribution.*[19]—The issue by the meteorological office of the daily charts of the weather in the Northern Hemisphere has enabled me to ascertain the barometric changes which take place from day to day in high latitudes. As a rule, the cyclones and anticyclones are large as compared with the polar uncharted area, and it proved possible to extend the isobars of the surrounding areas over the Arctic Sea. However, east Siberia could not, in the absence of the Japanese daily charts, which reach England about six months late, be dealt with.

From the partially completed charts the mean pressures were calculated for each day along latitudes 30°, 40°, 50°, 60°, 70°, and 80° north. When plotted they showed irregular periodic variations, some of which had a swing of something more than 25 days. As this is about the apparent period of rotation of the sun and pointed to our chief luminary as the cause of the variability of pressure from day to day, I decided to consider the sunspot question carefully.

By the courtesy of the Astronomer Royal, I have been supplied with bromide prints for each day for January, February, March, and April, and been allowed to see some of the later negatives of the solar disk. Also, by the courtesy of the director of the meteorological office, I have obtained the pressure charts—issued to the public since March—for January and February.

The sunspots have been plotted upon a diagram, the abscissæ of which are days and the ordinates degrees on the sun's surface measured from the apparent center of the disk. They clearly show the movements of each spot or group of spots, as they approach or recede from the center of the disk, owing to the sun's rotation.

An examination of this diagram demonstrates the fact that the pressure is low over the Arctic regions when there are sunspots near the sun's center, and that there are high pressures over the Arctic regions when there are no spots near the centre of the disk. Such low pressures due to sunspots occur in the long Arctic winter quite as markedly as they do during the summer. When the sun's disk was clear in the center on April 24, the mean pressure north of 60° was 1,025 millibars. On March 8 the mean pressure was 1,001 millibars and there were spots near the sun's center.

[19] Reprinted from *Nature*, London, Sept. 13, 1930.

I hope to be in a position to publish full details concerning the matter soon after the receipt of the Japanese weather charts of the North Pacific area for June.—*R. M. Deeley.*

*The bora.*—In a note on a recent geographical study of the vicinity of Fiume, at the north end of the Adriatic Sea (*Geogr. Rev.*, April, 1930, pp. 331–332), the following note on the bora appears:

> The bora blows when a "low" over the Adriatic or Mediterranean causes a draft of cold air to sweep "like a cascade" down the Dinaric mountain sides. Its vehemence is at a maximum in the gaps, where the air is compressed and condensed. The unexpected and capricious gusts (*refoli*) are particularly dangerous to navigation, but even on land they can easily upset a loaded railway car. Consequently the railways leaving Fiume are protected at the most exposed points by palisades and thick high walls.—*C. F. B.*

*City temperatures.*—The yearbook of the Baden weather service for 1929 has just been published.[20] This annual contains the usual summary of observations in Baden, both surface and aerological. Two scientific papers are also presented, one of them being on the temperature distribution in Karlsruhe on hot summer days.[21] In this paper Dr. Albert Peppler describes, in the form of temperature profiles and a detailed map, the local distribution of temperature in and about Karlsruhe. The observations are obtained by the temperature survey method by automobile. The instrument used was an Assmann aspiration thermometer.

Most striking is the exceptional contrast in evening temperatures between the interior of Karlsruhe and the wooded surroundings. The hottest parts of Karlsruhe had temperatures exceeding 30° C., while the woods nearby had temperatures from 25° down to below 23°. Owing to the marked contrast there was a slow flow of cool air from the country towards the city, this flow being marked on the streets entering the city. The heated air of the city flowing out over the surrounding countryside produced such a sharp inversion of temperature that the locomotive and other smoke was closely held to a low ceiling.—*C. F. B.*

*Rain map of Australia for 1929.*—Every year the Commonwealth meteorologist publishes a rain map of Australia on a scale of 130 miles to the inch. This map for 1929 shows many interesting contrasts. The least rainfall was 0.65 inch in the northeastern corner of south Australia. This was lowest on record for the station. The greatest rainfall was 120 inches at Innisfail, at latitude 17½ on the coast of Queensland. There was a rainfall of 110 inches near Port Macquarie about latitude 32 on the coast of South Wales. This was the greatest on record at that place. Tasmania had even more, the maximum exceeding 150 inches on the western mountains. Spots in the southeastern lowland, however, had less than 20 inches.

Printed in the space around the map is a table and discussion of the rainfall of the year by districts, also small-scale maps of Australia showing the distribution of areas having more or less than average rainfall. On the back of the map are 12 smaller scaled maps showing the rainfall by months. In January, February, and March monthly rainfalls of 30 to over 40 inches occurred on parts of the coast of Queensland.—*C. F. B.*

*Climatological summary for Chile, August, 1930, by J. Bustos Navarrete, Observatorio del Salto, Santiago, Chile.*—During the first half of the month atmospheric

[20] Meteorologisches Jahrbuch für 1929, Veröffentlichungen der Badischen Landeswetterwarte, Nr. 16, Karlsruhe, 1930.

[21] Albert Peppler, Die Temperaturverhältnisse von Karlsruhe an heissen Sommertagen, pp. 59–60, 2 figs.

conditions were relatively stable with moderate increase in temperature, but during the last decade there was a change to decidedly unsettled weather and general rains.

The most important depressions, all crossing the extreme southern region, were mapped on the 21st to 23d, 25th to 26th, and 28th to 30th.

Anticyclones, advancing from southern Chile toward Argentina, were mapped in the following periods: 1st to 5th, 11th to 13th, and 14th to 21st. In the period 6th to 9th an antarctic HIGH crossed the continent in a northerly direction.—*Translated by W. W. R.*

*Climatological summary for Chile, September, 1930, by J. Bustos Navarrete, Observatorio del Salto, Santiago, Chile.*—Like September this month was characterized by settled atmospheric conditions. Cyclonic storms of importance appeared in the extreme south during the periods 21st to 22d and 29th to 30th. During the remainder of the month anticyclonic areas dominated conditions and the weather was fine. The important HIGHS, all of which moved from southern Chile toward Argentina, were charted in the periods 2d to 12th, 13th to 17th, and 22d to 26th.—*Translated by W. W. R.*

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C FITZHUGH TALMAN, in charge of Library

## RECENT ADDITIONS

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# SOLAR OBSERVATIONS

## SOLAR AND SKY RADIATION MEASUREMENTS DURING OCTOBER, 1930

By HERBERT H. KIMBALL

For reference to descriptions of instruments and exposures, and an account of the method of obtaining and reducing the measurements, the reader is referred to this volume of the REVIEW, page 26.

Table 1 shows that solar radiation intensities averaged close to the normal intensity for October at Washington, D. C., and Lincoln, Nebr., and slightly below normal at Madison, Wis.

Table 2 shows an excess in the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky at Washington, New York, Fresno, and La Jolla, and a slight deficiency at Chicago, Madison, and Lincoln. The excess was marked at Washington.

Skylight polarization measurements obtained at Washington on six days during the month give a mean of 52 per cent and a maximum of 55 per cent on the 4th. At Madison, measurements obtained on four days give a mean of 54 per cent and a maximum of 61 per cent on the 10th. The values for both stations are considerably below the corresponding October averages for the respective stations.

TABLE 1.—*Solar radiation intensities during October, 1930*

[Gram-calories per minute per square centimeter of normal surface]

Washington, D. C.

| Date | Sun's zenith distance: 8 a.m. | 78.7° | 75.7° | 70.7° | 60.0° | 0.0° | 60.0° | 70.7° | 75.7° | 78.7° | Noon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75th mer. time | Air mass: A. M. | | | | | P. M. | | | | Local mean solar time |
| | c. | 5.0 | 4.0 | 3.0 | 2.0 | 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | c. |
| | mm | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | cal. | mm. |
| Oct. 1 | 6.27 | 0.77 | 0.87 | 1.07 | 1.16 | | | | | | 5.36 |
| Oct. 2 | 5.70 | 0.70 | 0.80 | 1.08 | 1.24 | 1.48 | 1.23 | 1.03 | 0.92 | 0.80 | 4.95 |
| Oct. 3 | 6.27 | | | | 1.09 | | | | | | 6.27 |
| Oct. 4 | 6.76 | | | | 1.08 | | 1.18 | 1.05 | 0.90 | 0.75 | 4.95 |
| Oct. 6 | 6.02 | 0.85 | 0.96 | 1.08 | 1.24 | 1.56 | | | | | 5.79 |
| Oct. 7 | 6.70 | 0.67 | 0.78 | 0.81 | 1.03 | 1.27 | | | | | 5.79 |
| Oct. 11 | 10.21 | 0.50 | 0.63 | 0.77 | 0.90 | | | | | | 9.83 |
| Oct. 17 | 11.81 | | | 0.71 | | | | | | | 10.21 |
| Oct. 18 | 5.36 | 0.78 | 0.93 | 1.08 | | | | | | | 3.45 |
| Oct. 20 | 2.16 | 0.76 | 0.96 | 1.08 | 1.33 | | 1.22 | | | | 1.96 |
| Oct. 22 | 3.45 | 0.66 | 0.78 | 0.91 | 1.08 | 1.34 | | | | | 3.45 |
| Oct. 23 | 4.96 | | | 0.91 | | | | | | | 3.30 |
| Oct. 24 | 6.50 | 0.67 | | 1.05 | 1.21 | | | | | | 4.37 |
| Oct. 28 | 7.57 | | | 1.03 | | | | | | | 6.76 |
| Oct. 30 | 5.16 | 0.62 | 0.71 | 0.91 | 1.05 | | | | | | 4.75 |
| Oct. 31 | 4.17 | 0.49 | 0.64 | | | | | | | | 3.81 |
| Means | | 0.68 | 0.81 | 0.96 | 1.13 | 1.41 | 1.21 | (1.04) | (0.91) | (0.78) | |
| Departures | | −0.07 | −0.02 | +0.01 | +0.01 | ±0.00 | +0.09 | +0.11 | +0.11 | +0.07 | |

TABLE 1.—*Solar radiation intensities during October, 1930*—Con.

[Gram-calories per minute per square centimeter of normal surface]

**Madison, Wis.**

| Date | Sun's zenith distance: 8 a.m. | 78.7° | 75.7° | 70.7° | 60.0° | 0.0° | 60.0° | 70.7° | 75.7° | 78.7° | Noon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 75th mer. time | Air mass: A. M. | | | | | P. M. | | | | Local mean solar time |
| | e. | 5.0 | 4.0 | 3.0 | 2.0 | [1] 1.0 | 2.0 | 3.0 | 4.0 | 5.0 | e. |
| | *mm.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *cal.* | *mm.* |
| Oct. 8 | 9. 47 | | | 0. 95 | 1. 07 | | | | | | 11. 38 |
| Oct. 10 | 13. 13 | | 0. 54 | 0. 66 | 0. 98 | | 1. 07 | | | | 16. 20 |
| Oct. 11 | 12. 68 | 0. 49 | 0. 61 | 0. 78 | 0. 96 | | 1. 04 | | | | 9. 47 |
| Oct. 13 | 11. 38 | | | 0. 83 | | | | | | | 10. 97 |
| Oct. 17 | 3. 30 | 0. 86 | | 0. 99 | 1. 31 | | | | | | 2. 03 |
| Oct. 21 | 2. 36 | | | | | | 1. 40 | | | | 3. 45 |
| Oct. 22 | 2. 74 | | | 1. 03 | | | | | | | 2. 87 |
| Oct. 24 | 4. 57 | | 0. 98 | 1. 11 | 1. 36 | 1. 59 | | | | | 3. 45 |
| Oct. 25 | 3. 30 | | 0. 92 | 1. 05 | 1. 18 | | 1. 20 | | | | 3. 99 |
| Means | | (0. 68) | 0. 76 | 0. 92 | 1. 14 | (1. 59) | 1. 18 | | | | |
| Departures | | −0. 09 | −0. 16 | −0. 12 | −0. 05 | | −0. 01 | | | | |

**Lincoln, Nebr.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 7 | 10. 97 | | | | | 1. 39 | 1. 18 | | | | 10. 21 |
| Oct. 8 | 11. 38 | | | 0. 97 | 1. 15 | 1. 43 | 1. 19 | 0. 99 | 0. 83 | 0. 72 | 13. 13 |
| Oct. 9 | 13. 13 | | | | | | 1. 18 | 0. 96 | 0. 84 | 0. 73 | 14. 10 |
| Oct. 10 | 13. 13 | 0. 79 | 0. 91 | 1. 04 | 1. 23 | 1. 47 | 1. 24 | 1. 08 | 0. 97 | 0. 87 | 11. 81 |
| Oct. 17 | 3. 15 | | | 1. 19 | 1. 37 | | | 1. 17 | 1. 04 | 0. 94 | 2. 05 |
| Oct. 19 | 1. 60 | | | | | | 1. 41 | 1. 20 | 1. 10 | 1. 01 | 1. 52 |
| Oct. 21 | 2. 74 | | 0. 91 | 1. 04 | | | | | | | 2. 87 |
| Oct. 23 | 3. 81 | | | 1. 09 | 1. 35 | | | | 1. 04 | 0. 93 | 5. 16 |
| Oct. 25 | 5. 79 | 0. 92 | 1. 02 | 1. 16 | 1. 30 | | 1. 27 | | | | 7. 04 |
| Oct. 27 | 5. 56 | 0. 80 | 0. 89 | 1. 14 | 1. 30 | 1. 48 | 1. 30 | 1. 13 | 1. 00 | 0. 89 | 4. 57 |
| Oct. 28 | 4. 37 | | 1. 00 | 1. 22 | 1. 39 | | | | | | 3. 30 |
| Oct. 29 | 3. 63 | | 1. 10 | 1. 20 | 1. 34 | | | | | | 3. 99 |
| Oct. 30 | 2. 49 | | 1. 05 | 1. 21 | 1. 40 | | | 1. 22 | 1. 08 | 0. 96 | 2. 62 |
| Oct. 31 | 2. 06 | | | | 1. 35 | | 1. 32 | | | | 2. 62 |
| Means | | 0. 84 | 1. 00 | 1. 13 | 1. 32 | 1. 44 | 1. 26 | 1. 11 | 0. 99 | 0. 88 | |
| Departures | | −0. 03 | +0. 05 | +0. 03 | +0. 04 | −0. 04 | +0. 01 | +0. 03 | +0. 04 | +0. 04 | |

[1] Extrapolated.

TABLE 2.—*Total solar radiation (direct + diffuse) received on a horizontal surface*

[Gram-calories per square centimeter]

| Week beginning | Average daily totals: Washington | Madison | Lincoln | Chicago | New York | Pittsburgh | Galnesville | Fresno | La Jolla | Miami |
|---|---|---|---|---|---|---|---|---|---|---|
| Oct. 1 | 486 | 204 | 275 | 163 | 332 | 249 | 460 | 442 | 374 | 502 |
| Oct. 8 | 320 | 234 | 303 | 199 | 221 | 200 | 402 | 387 | 377 | 459 |
| Oct. 15 | 395 | 196 | 270 | 162 | 209 | 211 | 441 | 393 | 241 | 349 |
| Oct. 22 | 368 | 229 | 312 | 152 | 176 | 160 | 390 | 368 | 284 | 407 |
| | Departures from weekly normals | | | | | | | | | |
| Oct. 1 | +155 | −65 | −48 | −42 | +79 | | | +11 | +12 | |
| Oct. 8 | +17 | −12 | +2 | +10 | −16 | | | −23 | +59 | |
| Oct. 15 | +113 | −25 | −30 | −9 | +1 | | | +12 | −29 | |
| Oct. 22 | +98 | +23 | +39 | −2 | −12 | | | +27 | +30 | |
| Accumulated departures on Oct. 28 | +8, 638 | +1, 155 | −2, 100 | +560 | +1, 260 | | | −2, 115 | −1, 526 | |

## POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. J. F. Hellweg, Superintendent United States Naval Observatory. Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, Perkins, and Mount Wilson Observatories. The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area including spots and groups, is given for each day in the last column]

| Date | Eastern standard civil time | Heliographic: Diff. long. | Longitude | Latitude | Area: Spot | Group | Total area for each day |
|---|---|---|---|---|---|---|---|
| 1930 | h m | ° | ° | ° | | | |
| Oct. 1 (Naval Observatory) | 10 45 | −10. 5 | 117. 6 | −3. 5 | | 154 | |
| | | +8. 0 | 136. 1 | +6. 0 | 108 | | 262 |
| Oct. 2 (Naval Observatory) | 11 3 | +3. 5 | 118. 2 | −4. 0 | | 185 | |
| | | +21. 5 | 136. 2 | +6. 0 | 93 | | 278 |
| Oct. 3 (Naval Observatory) | 10 47 | +17. 0 | 118. 6 | −4. 0 | | 123 | |
| | | +34. 5 | 136. 1 | +6. 0 | 93 | | 216 |
| Oct. 4 (Naval Observatory) | 10 42 | −80. 5 | 8. 0 | +6. 5 | | 278 | |
| | | −45. 5 | 43. 0 | −5. 0 | 2 | | |
| | | +31. 0 | 119. 5 | −4. 0 | 93 | | |
| | | +48. 0 | 136. 5 | +6. 0 | 77 | | 450 |

*Positions and areas of sun spots*—Continued

| Date | Eastern standard civil time | Heliographic: Diff. long. | Longitude | Latitude | Area: Spot | Group | Total area for each day |
|---|---|---|---|---|---|---|---|
| 1930 | h m | ° | ° | ° | | | |
| Oct. 5 (Naval Observatory) | 10 47 | −71. 0 | 4. 3 | +7. 0 | | 772 | |
| | | +42. 5 | 117. 8 | −4. 0 | | 93 | |
| | | +62. 0 | 137. 3 | +6. 5 | 93 | | 958 |
| Oct. 6 (Naval Observatory) | 10 42 | −58. 5 | 3. 6 | +7. 5 | | 880 | |
| | | +57. 0 | 119. 1 | −3. 5 | | 77 | |
| | | +75. 0 | 137. 1 | +6. 5 | 62 | | 1, 019 |
| Oct. 7 (Naval Observatory) | 10 43 | −45. 0 | 3. 9 | +8. 0 | | 679 | |
| | | +71. 0 | 119. 9 | −3. 0 | 62 | | 741 |
| Oct. 8 (Naval Observatory) | 12 32 | −29. 5 | 5. 2 | +8. 0 | | 772 | 772 |
| Oct. 9 (Naval Observatory) | 10 53 | −81. 5 | 300. 9 | +12. 0 | 15 | | |
| | | −17. 5 | 4. 9 | +7. 5 | | 694 | 709 |
| Oct. 10 (Naval Observatory) | 10 48 | −65. 5 | 303. 8 | +11. 5 | | 68 | |
| | | −4. 0 | 5. 3 | +7. 5 | | 756 | 824 |
| Oct. 11 (Naval Observatory) | 11 1 | −52. 5 | 303. 4 | +11. 5 | | 71 | |
| | | +9. 5 | 5. 4 | +7. 5 | | 509 | 580 |
| Oct. 12 (Naval Observatory) | 10 35 | −64. 5 | 278. 5 | −11. 5 | 3 | | |
| | | −38. 0 | 305. 0 | +10. 5 | | 139 | |
| | | +23. 0 | 6. 0 | +7. 0 | | 401 | 543 |
| Oct. 13 (Naval Observatory) | 12 20 | −23. 5 | 305. 4 | +10. 5 | | 185 | |
| | | +38. 0 | 6. 9 | +7. 5 | | 324 | 509 |
| Oct. 14 (Perkins Observatory) | 12 47 | −2. 0 | 313. 3 | +10. 0 | 93 | | |
| | | −9. 5 | 305. 8 | +12. 0 | 155 | | 248 |
| Oct. 15 (Naval Observatory) | 10 53 | +3. 5 | 306. 8 | +11. 0 | | 154 | |
| | | +66. 0 | 9. 3 | +6. 5 | | 170 | 324 |
| Oct. 16 (Naval Observatory) | 10 36 | +17. 0 | 307. 2 | +10. 5 | | 46 | 46 |
| Oct. 17 (Naval Observatory) | 10 48 | +33. 5 | 310. 5 | +10. 0 | | 12 | 12 |
| Oct. 18 (Naval Observatory) | 10 41 | +9. 0 | 272. 8 | +4. 0 | | 9 | |
| | | +40. 0 | 303. 6 | +13. 5 | | 46 | |
| | | +47. 5 | 311. 3 | +10. 5 | | 6 | 61 |
| Oct. 19 (Naval Observatory) | 10 45 | +52. 0 | 302. 6 | +13. 5 | | 93 | 93 |
| Oct. 20 (Naval Observatory) | 10 56 | +65. 0 | 302. 3 | +14. 0 | | 77 | 77 |
| Oct. 21 (Naval Observatory) | 12 4 | +78. 5 | 302. 0 | +14. 0 | 37 | | 37 |
| Oct. 22 (Naval Observatory) | 10 36 | −80. 0 | 131. 1 | −5. 5 | 185 | | |
| | | +23. 5 | 234. 6 | −20. 5 | 3 | | 188 |
| Oct. 23 (Naval Observatory) | 11 5 | −66. 5 | 131. 2 | −5. 5 | 185 | | |
| | | +37. 5 | 235. 2 | −20. 0 | | 9 | 194 |
| Oct. 24 (Naval Observatory) | 13 43 | −70. 0 | 113. 0 | −11. 5 | 6 | | |
| | | −53. 0 | 130. 0 | −6. 0 | | 278 | |
| | | −44. 5 | 138. 5 | +7. 5 | 3 | | 287 |
| Oct. 25 (Naval Observatory) | 13 15 | −38. 5 | 131. 6 | −5. 5 | | 324 | |
| | | +27. 5 | 197. 6 | +5. 0 | | 65 | 389 |
| Oct. 26 (Naval Observatory) | 11 12 | −26. 0 | 132. 0 | −5. 5 | | 293 | |
| | | +40. 0 | 198. 0 | +5. 0 | | 123 | 416 |
| Oct. 27 (Naval Observatory) | 11 40 | −29. 5 | 115. 1 | −10. 0 | | 56 | |
| | | −13. 0 | 131. 6 | −6. 0 | | 108 | |
| | | +53. 5 | 198. 1 | +5. 5 | | 154 | 318 |
| Oct. 28 (Naval Observatory) | 10 40 | −38. 5 | 93. 4 | −5. 0 | 3 | | |
| | | −18. 5 | 113. 4 | −6. 5 | | 31 | |
| | | −15. 5 | 116. 4 | −19. 0 | | 37 | |
| | | +0. 5 | 132. 4 | −60. 5 | | 386 | |
| | | +67. 5 | 199. 4 | +5. 0 | | 170 | 627 |
| Oct. 29 (Mount Wilson) | 12 0 | −5. 0 | 113. 0 | −7. 0 | | 52 | |
| | | −2. 0 | 116. 0 | −11. 0 | | 32 | |
| | | +7. 0 | 125. 0 | −7. 0 | | 24 | |
| | | +16. 0 | 134. 0 | −6. 0 | | 360 | |
| | | +85. 0 | 203. 0 | +6. 0 | | 21 | 489 |
| Oct. 30 (Naval Observatory) | 10 38 | +8. 0 | 113. 6 | −6. 5 | | 123 | |
| | | +12. 5 | 118. 1 | −10. 5 | | 93 | |
| | | +25. 5 | 131. 1 | −6. 5 | | 386 | 602 |
| Oct. 31 (Naval Observatory) | 11 18 | 0. 0 | 92. 0 | −8. 0 | | 6 | |
| | | +23. 0 | 115. 0 | −6. 0 | | 154 | |
| | | +25. 5 | 117. 5 | −10. 5 | | 62 | |
| | | +38. 5 | 130. 5 | −6. 5 | | 355 | 577 |
| Mean daily area for October | | | | | | | 414 |

## PROVISIONAL SUN-SPOT RELATIVE NUMBERS, OCTOBER, 1930 [1]

[Data furnished through the courtesy of Prof. W. Brunner, University of Zurich, Switzerland]

| October, 1930 | Relative numbers | October, 1930 | Relative numbers | October, 1930 | Relative numbers |
|---|---|---|---|---|---|
| 1 | 26 | 11 | 53 | 21 | 8 |
| 2 | a 30 | 12 | 48 | 22 | d -- |
| 3 | 26 | 13 | 56 | 23 | 18 |
| 4 | d 30 | 14 | 38 | 24 | 12 |
| 5 | | 15 | a 32 | 25 | Mc 29 |
| 6 | 43 | 16 | 24 | 26 | 28? |
| 7 | 39 | 17 | 11 | 27 | Ec 63 |
| 8 | 37 | 18 | 22 | 28 | b -- |
| 9 | 22 | 19 | 22 | 29 | b -- |
| 10 | Ebc 59 | 20 | 11 | 30 | 49 |
| | | | | 31 | 47 |

Mean (27 days) = 32.7.

[1] Dependent alone on observations at Zurich and its station at Arosa.

a = Passage of an average-sized group through the central meridian.
b = Passage of a large group through the central meridian.
c = New formation of a large or average-sized center of activity: E, on the eastern part of the sun's disk; W, on the western part; M, in the central zone.
d = Entrance of a large or average-sized center of activity on the east limb.

# AEROLOGICAL OBSERVATIONS

By RICHMOND T. ZOCH

Except for the upper levels at Due West and Ellendale the free-air temperatures were below normal at all levels at all stations. (See Table 1.) The departures were large at Royal Center.

The free-air relative humidities were mostly above normal at Broken Arrow, Due West, and Ellendale and were mostly below normal at Groesbeck and Royal Center. Free-air vapor pressures were mostly below normal at all stations except Ellendale, where they were above normal at nearly all levels.

There were only five airplane observations made during the month at the Seattle (Wash.) Naval Air Station. For this reason no mean was computed and accordingly this station has been omitted from Table 2.

At the surface the resultant winds were northerly for the eastern part of the country and were variable elsewhere. At the 1,000-meter level they were easterly over the southern part of the country, with westerly winds predominating elsewhere. At the 2,500-meter level the resultant winds were westerly all over the country except for the southwestern portion, where they were variable, and extreme southern portion, where they were southerly. At the 4,000-meter level and above, westerly winds predominated over all parts of the country.

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October, 1930*

TEMPERATURE (° C.)

| Altitude (meters) m. s. l. | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal |
| Surface | 14.0 | −2.9 | 14.3 | −1.8 | 5.0 | −2.2 | 15.9 | −3.1 | 10.5 | −2.6 |
| 500 | 13.7 | −2.1 | 13.2 | −1.2 | 5.0 | −2.3 | 16.4 | −1.5 | 9.8 | −2.0 |
| 1,000 | 12.8 | −1.0 | 10.6 | −1.5 | 3.9 | −2.7 | 14.7 | −1.0 | 7.0 | −2.3 |
| 1,500 | 11.1 | −0.7 | 8.4 | −1.5 | 3.2 | −1.8 | 13.0 | −0.7 | 4.2 | −2.7 |
| 2,000 | 8.9 | −0.7 | 6.5 | −1.6 | 1.8 | −1.0 | 10.9 | −0.6 | 1.9 | −2.5 |
| 2,500 | 6.2 | −0.8 | 4.6 | −1.5 | −0.6 | −0.9 | 8.3 | −0.9 | −0.5 | −2.6 |
| 3,000 | 3.2 | −1.0 | 2.7 | −1.1 | −2.3 | +0.2 | 5.6 | −1.3 | −2.5 | −2.1 |
| 4,000 | | | −1.1 | +0.5 | −6.4 | +1.7 | −2.0 | −3.9 | −7.4 | −1.8 |
| 5,000 | | | | | −11.6 | +1.9 | | | −12.8 | −1.9 |

TABLE 1.—*Free-air temperatures, relative humidities, and vapor pressures during October, 1930*—Continued

RELATIVE HUMIDITY (%)

| Altitude (meters) m. s. l. | Broken Arrow, Okla. (233 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (141 meters) | | Royal Center, Ind. (225 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal | Mean | Departure from normal |
| Surface | 73 | +6 | 66 | 0 | 80 | +12 | 83 | +9 | 69 | 0 |
| 500 | 67 | +4 | 62 | −2 | 79 | +13 | 65 | −3 | 63 | −2 |
| 1,000 | 60 | +1 | 64 | +1 | 72 | +14 | 57 | −8 | 62 | 0 |
| 1,500 | 55 | 0 | 60 | +1 | 59 | +6 | 47 | −13 | 59 | +2 |
| 2,000 | 49 | −1 | 54 | +2 | 53 | +3 | 42 | −12 | 52 | −1 |
| 2,500 | 48 | +2 | 50 | +3 | 55 | +7 | 45 | −3 | 46 | −2 |
| 3,000 | 47 | +4 | 44 | 0 | 58 | +12 | 53 | +11 | 43 | −2 |
| 4,000 | | | 24 | −16 | 57 | +12 | | | 48 | +6 |
| 5,000 | | | | | 36 | −6 | | | 29 | −4 |

VAPOR PRESSURE (*mb.*)

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Surface | 12.21 | −0.96 | 11.18 | −1.27 | 8.25 | +1.30 | 15.67 | −1.14 | 9.43 | −1.24 |
| 500 | 11.11 | −0.60 | 9.94 | −1.05 | 8.11 | +1.24 | 12.69 | −1.89 | 8.33 | −1.03 |
| 1,000 | 9.43 | −0.25 | 8.66 | −0.74 | 6.99 | +1.23 | 9.99 | −2.12 | 6.87 | −0.70 |
| 1,500 | 7.67 | −0.25 | 6.82 | −0.64 | 5.42 | +0.71 | 7.43 | −2.22 | 5.43 | −0.51 |
| 2,000 | 5.76 | −0.32 | 5.20 | −0.43 | 4.42 | +0.53 | 5.58 | −1.73 | 3.96 | −0.71 |
| 2,500 | 4.55 | −0.09 | 4.07 | −0.34 | 3.90 | +0.71 | 4.82 | −0.71 | 2.72 | −0.86 |
| 3,000 | 3.63 | +0.08 | 2.97 | −0.55 | 3.61 | +1.03 | 4.66 | +0.52 | 2.16 | −0.69 |
| 4,000 | | | 0.56 | −1.80 | 2.66 | +0.96 | | | 1.47 | −0.28 |
| 5,000 | | | | | 0.62 | 0.43 | | | | |

TABLE 2.—*Free-air data obtained at naval air stations during October, 1930*

| Altitude (meters) m. s. l. | Temperature (°C) | | | | Relative humidity (%) | | | |
|---|---|---|---|---|---|---|---|---|
| | Hampton Roads, Va. | Pensacola, Fla. | San Diego, Calif. | Washington, D. C. | Hampton Roads, Va. | Pensacola, Fla. | San Diego, Calif. | Washington, D. C. |
| Surface | 14.2 | 16.9 | 19.5 | 10.6 | 68 | 78 | 63 | 71 |
| 500 | 12.3 | 16.8 | 18.4 | 10.8 | 65 | 69 | 50 | 60 |
| 1,000 | 9.3 | 14.5 | 18.0 | 8.7 | 61 | 65 | 42 | 58 |
| 2,000 | 6.6 | 10.4 | 13.4 | 3.9 | 45 | 55 | 34 | 54 |
| 3,000 | 2.7 | 6.3 | 8.3 | 0.4 | 39 | 45 | 28 | 40 |
| 4,000 | | | | −4.7 | | | | 21 |

TABLE 3.—*Free air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during October, 1930*

| Altitude (meters) m.s.l. | Broken Arrow, Okla. (233 meters) | | Burlington, Vt. (132 meters) | | Cheyenne, Wyo. (1,873 meters) | | Due West, S. C. (217 meters) | | Ellendale, N. Dak. (444 meters) | | Groesbeck, Tex. (139 meters) | | Havre, Mont. (762 meters) | | Jacksonville, Fla. (65 meters) | | Key West, Fla. (11 meters) | | Los Angeles, Calif. (145 meters) | | Spokane, Wash. (606 meters) | | Modena, Utah (1,665 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity |
| | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | |
| Surface | S 31 E | 1.2 | S 12 E | 1.4 | N 73 W | 2.8 | N 25 E | 1.5 | N 58 W | 2.3 | N 52 E | 1.2 | N 71 W | 1.4 | N 14 E | 2.5 | N 62 E | 3.1 | N 53 W | 2.6 | S 12 E | 1.0 | S 73 W | 2.6 |
| 500 | S 10 W | 4.3 | S 39 W | 2.0 | | | N 42 E | 2.3 | N 60 W | 2.8 | S 43 E | 4.1 | | | N 48 E | 5.8 | N 79 E | 6.6 | N 65 E | 0.7 | | | | |
| 1,000 | S 39 W | 5.5 | N 77 W | 3.1 | | | N 15 E | 1.3 | N 64 W | 5.5 | S 18 E | 3.4 | S 80 W | 3.1 | N 57 E | 3.4 | S 83 E | 4.8 | S 80 E | 0.8 | S 34 W | 2.2 | | |
| 1,500 | S 63 W | 4.9 | N 74 W | 2.6 | | | N 15 W | 3.8 | N 54 W | 6.8 | S 9 W | 1.3 | N 70 W | 4.7 | N 20 W | 0.5 | S 69 E | 3.2 | S 24 E | 1.3 | S 53 W | 2.6 | | |
| 2,000 | N 77 W | 4.7 | N 82 W | 2.8 | N 78 W | 4.5 | N 58 W | 4.0 | N 60 W | 6.9 | N 84 W | 1.2 | N 73 W | 5.0 | N 42 W | 2.9 | S 81 E | 1.4 | S 72 E | 1.2 | S 66 W | 4.6 | N 23 E | 0.1 |
| 2,500 | N 57 W | 4.2 | N 87 W | 3.8 | N 87 W | 7.9 | N 64 W | 6.2 | N 63 W | 5.8 | N 43 W | 2.4 | N 67 W | 4.9 | N 49 W | 3.7 | S 16 E | 0.5 | N 74 E | 1.0 | S 78 W | 5.5 | N 61 E | 0.7 |
| 3,000 | S 46 W | 3.2 | S 62 W | 4.8 | N 70 W | 9.4 | N 73 W | 6.2 | N 65 W | 7.5 | N 44 W | 3.3 | N 68 W | 6.3 | N 68 W | 4.8 | S 47 W | 1.0 | N 45 W | 1.6 | S 82 W | 9.2 | N 64 W | 1.2 |
| 4,000 | | | S 70 W | 4.9 | N 76 W | 9.9 | N 75 W | 10.1 | | | N 45 W | 5.5 | N 23 W | 0.8 | N 73 W | 6.3 | N 76 W | 3.3 | N 56 W | 4.0 | | | N 65 W | 4.7 |
| 5,000 | | | | | S 73 W | 7.6 | N 64 W | 10.2 | | | | | | | N 81 W | 9.4 | N 74 W | 5.7 | | | | | N 54 W | 6.8 |

TABLE 3.—*Free air resultant winds (meters per second) based on pilot balloon observations made near 7 a. m. (E. S. T.) during October, 1930*—Continued

| | Medford, Oreg. (410 meters) | | Memphis, Tenn. (145 meters) | | New Orleans, La. (25 meters) | | Omaha, Nebr. (321 meters) | | Royal Center, Ind. (225 meters) | | Salt Lake City, Utah (1,294 meters) | | San Francisco, Calif. (2 meters) | | Sault Ste. Marie, Mich. (198 meters) | | Seattle, Wash. (14 meters) | | Washington, D. C. (10 meters) | | Phoenix, Ariz. (356 meters) | | Brownsville, Tex. (12 meters) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity | Direction | Velocity |
| | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | | ° | |
| Surface | S 15 E | 0.6 | N 73 E | 0.8 | N 53 E | 2.0 | S 6 W | 0.4 | S 18 W | 0.7 | S 36 E | 2.2 | W | 0.4 | Calm. | ---- | S 27 E | 1.3 | N 38 W | 0.5 | S 84 E | 2.4 | N 62 E | 0.7 |
| 500 | S 26 E | 0.1 | N 65 E | 0.7 | S 89 E | 6.5 | S 51 W | 2.6 | S 50 W | 3.4 | ---------- | ---- | N 29 E | 2.3 | S 74 W | 1.6 | S 11 W | 3.2 | N 26 W | 4.4 | S 87 E | 2.6 | S 69 E | 5.7 |
| 1,000 | S 2 W | 0.7 | S 87 W | 0.7 | S 74 E | 4.3 | S 80 W | 5.0 | S 74 W | 3.8 | ---------- | ---- | N 23 E | 4.9 | N 76 W | 4.2 | S 35 W | 2.8 | N 27 W | 5.8 | S 60 E | 1.9 | S 50 E | 5.1 |
| 1,500 | S 31 E | 0.7 | N 52 W | 2.6 | S 85 E | 2.2 | N 85 W | 7.0 | N 75 W | 4.7 | S 23 E | 2.6 | N 2 E | 4.4 | N 78 W | 3.7 | S 71 W | 1.3 | N 25 W | 5.1 | S 26 E | 2.2 | S 44 E | 3.2 |
| 2,000 | N 84 W | 0.9 | N 26 W | 2.9 | N 27 E | 1.6 | N 78 W | 6.3 | N 64 W | 5.6 | S 20 W | 1.2 | N 1 W | 4.4 | N 69 W | 5.9 | S 40 W | 4.3 | N 39 W | 6.9 | S 10 W | 0.9 | S 37 E | 2.3 |
| 2,500 | S 85 W | 2.9 | N 14 W | 4.3 | N 21 E | 1.1 | N 88 W | 7.7 | N 74 W | 5.9 | S 87 W | 1.5 | N 5 W | 5.0 | N 80 W | 6.5 | S 56 W | 6.4 | N 59 W | 6.9 | S 21 W | 3.3 | S 10 E | 2.8 |
| 3,000 | N 68 W | 3.9 | N 16 E | 4.0 | N 19 W | 2.4 | N 78 W | 7.8 | N 82 W | 7.3 | N 54 W | 2.0 | N 1 W | 5.2 | S 75 W | 6.2 | S 63 W | 8.3 | N 42 W | 7.2 | S 46 W | 4.2 | S 18 W | 2.7 |
| 4,000 | N 34 W | 4.7 | ---------- | ---- | N 2 W | 4.8 | ---------- | ---- | N 61 W | 1.2 | N 82 W | 4.1 | N 17 W | 5.5 | ---------- | ---- | ---------- | ---- | ---------- | ---- | N 76 W | 2.8 | S 54 W | 5.4 |
| 5,000 | ---------- | ---- | ---------- | ---- | ---------- | ---- | ---------- | ---- | S 39 W | 1.4 | ---------- | ---- | N 30 W | 6.3 | ---------- | ---- | ---------- | ---- | ---------- | ---- | ---------- | ---- | ---------- | ---- |

TABLE 4.—*Observations by means of kites, captive and limited-height sounding ballons during October, 1930*

| | Broken Arrow, Okla. | Due West, S. C. | Ellendale, N. Dak. | Groesbeck, Tex. | Royal Center, Ind. |
|---|---|---|---|---|---|
| Mean altitudes (meters) m. s. l., reached during month | 2,824 | 2,653 | 2,508 | 2,469 | 2,716 |
| Maximum altitude (meters) m. s. l., reached and date | [1] 3,978 | [2] 4,784 | [3] 5,080 | [4] 4,233 | [5] 4,986 |
| Number of flights made | 24 | 32 | 31 | 22 | 28 |
| Number of days on which flights were made | 24 | 31 | 29 | 22 | 28 |

[1] 24th. [2] 11th. [3] 8th. [4] 26th. [5] 16th.

In addition to the above there were approximately 130 pilot balloon observations made daily at 56 Weather Bureau stations in the United States.

# WEATHER IN THE UNITED STATES

## THE WEATHER ELEMENTS

By M. C. BENNETT

### GENERAL SUMMARY

Except during the first few days, the first half of October was warmer than usual over the eastern two-thirds of the country, the temperature being especially high in the central and northern regions, while in the western third near normal temperatures prevailed. During the latter half of the month much colder weather prevailed with generally subnormal temperatures from the Mississippi Valley eastward.

The precipitation for October was heavy throughout most of the Plains States and in the west Gulf area, where some sections received from two to six times the monthly normal. The northern Plains, and the northern Rocky Mountain States had much more than the average, and the States just west of the Mississippi River and the east Gulf States received amounts near the normal, while the monthly totals were much below the average in most of the Lake region and from the Ohio Valley eastward. The scantiest falls again occurred in the interior of the Middle Atlantic States, portions of which received less than one-fourth of the October average. The far Southwest and portions of the Great Basin and Pacific Coast States also received scanty precipitation.

### TEMPERATURE

October was the first month since January to average cooler than normal over much more than half of the country. Conditions changed considerably from week to week, but for the month no State averaged more than slightly warmer than normal and but few more than moderately cooler than normal.

The first week was cool east of the Mississippi River but warm over most districts to westward, especially in the lower Missouri Valley and the far Northwest. The second week was warmer than normal practically everywhere save west of the Rocky Mountains, and was particularly warm in the north-central portion. From the middle of the month onward cool weather predominated, except in the far Southwest. A marked cold period visited Montana and the Dakotas late in the middle decade of the month and passed southeastward to the Atlantic coast by the first portion of the final decade. In addition, the closing days of October were quite cold in the north-central portion of the country.

The month averaged cooler than normal in most regions, especially in the southern Appalachian area, in Indiana and adjacent districts, and from the central portions of the Dakotas westward to the Cascade Mountains. A large part of Montana averaged more than 4° colder than normal.

Portions of California and of the Rio Grande Valley averaged warmer than normal, also some parts of the Lake region and New England.

The highest temperatures in the far Northwest were noted early in the month, but in most States west of the Mississippi late in the first decade. From the central valleys northeastward and eastward the highest marks were reached usually during the period from the 11th to the 14th, and in a few States they were close to the previous records of October high temperatures.

The lowest marks were reached about the 17th in the northern portions of the Plains and the Rocky Mountains, and about the 22d in the majority of States east of the Mississippi River. Several States of the upper Ohio Valley, or the middle or south Atlantic coast equaled or very closely approached their previous October records at this time. In some of the Southeastern States and in most of the States west of the Mississippi River the lowest marks occurred during the last six days of October.

### PRECIPITATION

There was heavy precipitation during the first week of October over nearly all of Texas and considerable over the Plains region and most of Wyoming, Arkansas, and western Louisiana. During the second week there was much better distribution, with moderately large falls in portions of the Southeast and the near Southwest, and of the Plateau and Pacific coast regions, also in the vicinity of Lake Michigan. From the middle of October onward to the end there usually was less precipitation than during the first fortnight, yet considerable occurred in the Pacific Northwest, in the west Gulf region and near Southwest, in the Northeast, and just before the month closed, from southeastern Louisiana to southern Virginia.

The month brought much more than October's normal precipitation to the Plains region, especially the western portion, and to practically all parts of Texas. There was usually somewhat more than normal in eastern Idaho, Wyoming, and southern and western Montana, also in Arkansas and Louisiana. Most other districts west of the Mississippi River received less than normal, especially California, southern Oregon and Arizona, and the middle Missouri Valley.

East of the Mississippi River almost every State averaged drier than normal, with notable shortages in the Ohio Valley and from Pennsylvania southwestward over the southern Appalachians. There was somewhat more than normal in certain parts of the Southeast, in some New England coast districts, and in northern Illinois.

### SNOWFALL

October brought comparatively little snowfall, considering the country as a whole.

In the southernmost States of the far West, even the loftiest stations had but scanty snowfall, but most highland stations of Washington, of the middle and northern Plateau, and of the middle and northern Rocky Mountain region had moderate amounts.

From northeastern Washington eastward to Montana and southeastward to central Nebraska there was a considerable fall for October about the 14th to 18th.

From northern Minnesota eastward to the Adirondack region considerable snow occurred about the 16th to 20th, with notably heavy falls over the northern half of Michigan on the 17th and 18th.

Northern New England was visited by a moderately heavy snowstorm about the 24th, and most of Iowa and eastern Nebraska, with some portions of adjoining States, by a moderate fall on the 29th and 30th.

### SUNSHINE AND RELATIVE HUMIDITY

Much cloudy weather prevailed in the northern border States, but generally the southern two-thirds of the country, except the Florida Peninsula and southern Texas, had a large amount of sunshine, and the southern half of the Rocky Mountains and westward to the Pacific had considerably more than the average, while southwestern Arizona and southeastern California received from 90 to 97 per cent of the possible.

The relative humidities were generally below the normal in the Mississippi Valley and eastward as far north as the lower Lake region and southern portions of New York and the New England States; also in the Pacific States and far Southwest they were below the average. Elsewhere the humidities were generally above the normal, but with no unusual departures therefrom.

## SEVERE LOCAL STORMS, OCTOBER, 1930

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

| Place | Date | Time | Width of path yards [1] | Loss of life | Value of property destroyed | Character of storm | Remarks | Authority |
|---|---|---|---|---|---|---|---|---|
| Elk Creek, Colo. | 3 | | | | | Destructive hail | No details reported | Official, U. S. Weather Bureau. |
| Forest District, N. Mex. | 5 | P. m. | 2-4 mi. | | $5,000 | Hail | Crops and buildings damaged; stock injured | Do. |
| Opelousas, La. | 7 | 8:30 a. m. | 100 | | 30,000 | Tornado | Cotton compress demolished; several houses damaged; path 200 yards. | Do. |
| Yakima and Spokane Counties, Wash. | 14 | | | | | Wind | Apples blown off | Do. |
| Field, N. Mex. (near) | 15 | | 2-4 mi. | | 5,000 | Hail | Crops and buildings damaged; stock hurt | Do. |
| New Burnside, Ill. | 16 | | | | | Wind and electrical. | Several small buildings blown down; a house damaged; and a cow killed. | Do. |
| Buffalo, N. Y., to Erie, Pa. | 18-19 | | | | | Snow | Highways obstructed; apple trees broken; telephone and power lines down in places; transportation lines hampered; roofs collapsed. | Do. |
| Roswell, N. Mex. (22 miles southeast) | 1 | 1-2 a. m. | | | | Hail | Cotton and apples severely damaged | Do. |
| Hope, N. Mex. | 1 | P. m. | 2 mi. | | 27,000 | do | Crops and fruit damaged; sheep and goats killed or injured; roofs pierced. | Do. |
| Roswell, N. Mex. | 1 | do | 1,760-2,640 | | 90,000 | do | Cotton and alfalfa beaten, windows broken, buildings damaged, car tops perforated. | Do. |
| Carlsbad, N. Mex. | 1-2 | | | | | Hail and rain | Heavy damage to crops, houses and trees | Do. |
| Pennington, N. Mex. | 1-2 | | | | | Hail | Crops and other property damaged; stock injured | Do. |
| Fowler, Colo. (near) | 2 | 3 p. m. | 880 | 3 | 30,000 | Tornado and hail | Houses, farm buildings and equipment and 3 autos totally wrecked; 3 persons injured. | Do. |
| Peetz, Colo. | 2 | 5:30 p. m. | 9 mi. | | | Hail | Windows and roofs pierced | Do. |
| Atoka, N. Mex. | 2 | P. m. | 1-2 mi. | | | Rain and hail | Crops ruined; roofs and autos damaged; stock injured. | Do. |
| Parker, Colo. | 3 | 3-3:15 p.m. | 8 mi. | | | Hail | Roofs, windows, and auto tops damaged | Do. |
| Byers, Colo. | 3 | 5:30 p. m. | 3-4 mi. | | 10,000 | do | Stock injured; poultry killed | Do. |
| Artesia and Stead, N. Mex. | 3 | P. m. | | | | do | Extensive crop loss; other property damage | Do. |

[1] "Mi." signifies miles instead of yards.

## RIVERS AND FLOODS

By R. E. SPENCER

Floods during October, confined chiefly to the rivers of Texas, were in the main of little consequence. Exceptions were those in the Rio Grande and the Brazos, $15,000 damage having occurred near Del Rio, Tex., on the Rio Grande, and $14,000 in the vicinity of Waco. Tex., on the Brazos. The Rio Grande loss was the result of damage to dam construction works; that on the Brazos was distributed as follows:

| | |
|---|---|
| Tangible property | $7,000 |
| Unharvested crops (7,000 acres) | 5,000 |
| Suspension of business | 2,000 |

In addition, "considerable" crop losses are reported to have resulted from overflows along Brazos River tributaries.

High stages continue in the Trinity River at Dallas, Tex., as a result of dams used in levee work in progress below the gage.

The official in charge of the Weather Bureau office at Pittsburgh, Pa., comments as follows upon river conditions in his district: [1]

Navigation was suspended on account of low water in the Monongahela River above the seventh pool, about July 24, when it became impossible to maintain pool-full stages. On that date the lower gage at lock No. 10 showed 6.0 feet, which was 1.3 feet below the crest of dam No. 8, 11 miles below. By September 1 the stage at No. 10 had dropped to 4.0 feet, which was 3.3 feet below the crest of dam No. 8, and by October 1 the stage at No. 10 was down to 1.3 feet, and remained at that stage throughout the month, due to a pool formed by shoals about 1,000 feet below the dam. The only water feeding the pool was the leakage through lock and dam No. 10. The upper gage at lock No. 8 showed 0.8 foot of water October 31, which meant that the pool was empty. A stream flow measurement at lock No. 10, by the United States Army Engineers, the latter part of October, showed the flow to be 5 second-feet.

[1] Cf. p. 401.

[All dates in October except as otherwise specified]

| River and station | Flood stage | Above flood stages—dates | | Crest | |
|---|---|---|---|---|---|
| | | From— | To— | Stage | Date |
| MISSISSIPPI DRAINAGE | | | | | |
| | *Feet* | | | *Feet* | |
| Republican: Concordia, Kans. | 8 | 15 | 15 | 8.2 | 15 |
| Canadian: | | | | | |
| Canadian, Tex. | 5 | 12 | 12 | 6.0 | 12 |
| Union City, Okla. | 7 | 13 | 14 | 8.2 | 14 |
| North Canadian: Woodward, Okla. | 4 | 13 | 13 | 4.0 | 13 |
| Ouachita: Arkadelphia, Ark. | 12 | 8 | 8 | 16.2 | 8 |
| WEST GULF DRAINAGE | | | | | |
| Trinity: Dallas, Tex. | 25 | 8 | 8 | 25.8 | 8 |
| Brazos: Waco, Tex. | 27 | 6 | 7 | 30.7 | 6 |
| Colorado: | | | | | |
| Austin, Tex. | 18 | 7 | 8 | 22.5 | 7 |
| | | 18 | 18 | 18.0 | 18 |
| Columbus, Tex. | 28 | 10 | 12 | 30.8 | 11 |
| | | 19 | 21 | 31.9 | 21 |
| Rio Grande: | | | | | |
| Del Rio, Tex. | 10 | 5 | 6 | 15.5 | 6 |
| | | 15 | 15 | 11.1 | 15 |
| Eagle Pass, Tex. | 16 | 7 | 7 | 17.1 | 7 |
| San Benito, Tex. | 23 | 11 | 12 | 23.7 | 11 |
| | | 19 | 22 | 24.1 | 21 |
| | | 25 | 25 | 23.0 | 25 |
| | | 31 | 31 | 23.0 | 31 |
| Pecos: Pecos, Tex. | 11 | 19 | 19 | 12.0 | 19 |

# WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

## NORTH ATLANTIC OCEAN

By F. G. TINGLEY

October may be said to inaugurate the winter season on the North Atlantic inasmuch as the average number of gales north of the forty-fifth parallel is sufficient to call for winter freeboard after the 16th of the month for vessels using the more northerly trans-Atlantic routes. There are, however, variations from one year to another in the number of gales as well as in their intensity and geographical distribution. In the month under review the number of gales reported was very close to the normal. More were reported than in October, 1929, but considerably fewer than in October, 1928, which was regarded as an exceptionally stormy month, especially over the middle and eastern portions of the ocean.

The distribution of pressure, as shown in Table 1, did not vary greatly from normal, except for the region north of the British Isles. Here low pressure prevailed, as shown by the negative departure of 0.26 inch at Lerwick, Shetland Islands. The average departure from normal for this group of 13 stations was, for the month under review, 0.08 inch. In October, 1928, a month of fewer gales, the group departure was 0.07 inch, while in October, 1928, just referred to as a stormy month, it rose to 0.10 inch.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian). North Atlantic Ocean, October, 1930*

| Stations | Average pressure | Departure | Highest | Date | Lowest | Date |
|---|---|---|---|---|---|---|
| | *Inches* | *Inch* | *Inches* | | *Inches* | |
| Julianehaab, Greenland | 29.76 | (1) | 30.28 | 7th | 29.18 | 19th. |
| Belle Isle, Newfoundland | 30.01 | [2] +0.14 | 30.48 | 8th | 29.60 | 19th. |
| Halifax, Nova Scotia | 29.98 | [3] −0.06 | 30.38 | 8th [4] | 29.38 | 26th. |
| Nantucket | 30.01 | [3] −0.07 | 30.30 | 12th [4] | 29.26 | 25th. |
| Hatteras | 30.06 | [3] −0.04 | 30.36 | 22d | 29.78 | 15th. |
| Key West | 29.95 | [3] −0.01 | 30.16 | 31st | 29.82 | 1st. |
| New Orleans | 30.05 | [3] −0.01 | 30.50 | 31st | 29.82 | 28th. |
| Cape Gracias, Nicaragua | 29.83 | [2] −0.09 | 29.94 | 21st [4] | 29.74 | 2d. |
| Turks Island | 30.00 | [3] +0.05 | 30.10 | 21st | 29.90 | 2d. |
| Bermuda | 29.96 | [3] −0.11 | 30.18 | 29th | 29.66 | 25th. |
| Horta, Azores | 30.14 | [2] +0.02 | 30.46 | 22d | 29.48 | 14th. |
| Lerwick, Shetland Islands | 29.53 | [3] −0.26 | 30.46 | 2d | 29.01 | 24th. |
| Valencia, Ireland | 29.77 | [3] −0.14 | 30.19 | 3d | 29.12 | 17th. |
| London | 29.86 | [3] −0.05 | 30.42 | 2d | 29.28 | 8th. |

[1] No normal available.
[2] From normals shown on Hydrographic Office Pilot Charts, based on observations at Greenwich mean noon, or 7 a. m., seventy-fifth meridian time.
[3] From normals based on 8 a. m. observations.
[4] On other date or dates.

Fog was reported on from 10 to 12 days over the Grand Banks; on from 5 to 6 days along the American coast north of Cape Cod, and on from 1 to 5 days over the central portion of the northern steamer lanes. Vessel reports received show only 5 occurrences of fog during October east of the fifteenth meridian.

The month opened with pressure distribution in the eastern part of the ocean completely reversed from the normal, high pressure overlying the region of Iceland and the British Isles and low pressure that between the Azores and Spanish Peninsula. This distribution occasioned moderate to fresh northerly to northeasterly gales between the Azores and English Channel. A moderate depression lay on the 1st between Bermuda and the Florida coast. During the period from the 1st to 5th normal pressure distribution was restored over the eastern part of the ocean, pressure falling from 30.40 inches to 29.12 inches at Vestmanno (Iceland), and rising from 29.88 inches to 30.40 inches at Horta. At the same time the depression in the western Atlantic moved northward with increasing intensity to the vicinity of Nova Scotia, where it prevailed on the 5th as a severe storm. On this day the Dutch steamship *Yselhaven*, in latitude 41° 44′ N., longitude 61° 50′ W., reported a southwest hurricane. Reports of other vessels involved in this storm will be found in the accompanying Gale and Storm Report. At least one casualty occurred in the fishing fleets of this region, the schooner *Lake O'Law* foundering on the 6th.

During the 6th and 7th the storm diminished in intensity and was forced to the southward apparently by the advance of a high pressure area from the continent. However, with some reinforcement from the southward it again acquired a northerly to northeasterly movement on the 9th and during the following days moved slowly to a position in midocean. On this part of its path it was attended by gales, chiefly on its western side, and for the most part only moderate to fresh in force. By the 15th it had again turned northward and had reached a position immediately to the south of Iceland. Meanwhile pressure had fallen over the entire northern part of the ocean so that the western depression appeared as the center of an extensive cyclone. Pressure at Vestmanno on the morning of the 15th was 28.80 inches and as far south as Horta was 29.78 inches, the entire ocean between Newfoundland and the British Isles being covered by a great barometric depression. The wind movement at this time, as reported by vessels within the region of low pressure, was for the most part moderate in character although a few vessels on the more northerly routes experienced full hurricane winds.

From the 15th to 18th low pressure prevailed in the southwestern part of the Gulf of Mexico, apparently being part of a general depression covering lower Mexico and adjacent waters of both the Pacific and the Gulf. On the morning of the 19th a center developed on the Gulf coast and during the day moderate to strong gales were experienced by vessels in the vicinity. However by the morning of the 20th the disturbance had lost energy and on the 21st the entire Gulf, except the Bay of Campeche, was covered by the southern part of an extensive continental area of high pressure. With the southerly advance of this area a heavy norther prevailed at Tampico on the 19th and 20th and vessels were unable to enter port. Press accounts state that 10 vessels that had been held outside entered on the 21st.

Between the 15th and 20th pressure rose strongly in the region of the Azores and the northern depression moved very slowly eastward, with some contraction in size. On the latter date its center lay between Iceland and Scotland. On the 19th the British S. S. *Cameronia*, bound from Glasgow to Boston, reported a barometer of 28.32 inches and a westerly storm, force 11. This was in 56° N., 12° W. For the most part, however, only moderate to fresh gales were reported by vessels within the region covered by the depression. On the more southerly steamship routes the weather of this period was distinctly favorable.

After the 20th the northeastern depression spread to the southward and on the 22d a second center developed over the western Mediterranean. The whole of Central Europe and neighboring waters to the north and south thus came under cyclonic influence. However on the 26th a high-pressure area from the ocean pushed eastward over southwestern Europe and the close of the month saw anticyclonic conditions established over the whole of the western Mediterranean and adjacent continental regions. The advance of the HIGH caused a heavy northwest gale on the south coast of France on the 26th and 27th.

In the western Atlantic a depression developed northeast of Bermuda on the 23d and during the following day moved to the vicinity of the Grand Banks attended by northerly gales in the western quadrants. It was followed by a more energetic disturbance that formed to the southwest of Bermuda and which by the morning of the 25th had advanced to a position between Nantucket and Sable Island. This latter depression moved slowly in an east-northeast direction and on the morning of the 27th its center lay just to the south of Cape Race. Meanwhile its predecessor, moving more rapidly, had reached the vicinity of Iceland. These two disturbances caused moderate to strong gales over the western section of the trans-Atlantic steamship lanes from the 24th to 27th. After the latter date the second of the two disturbances advanced with some rapidity to the northeastward and merged with a low-pressure area lying between Iceland and the Scandinavian Peninsula. On the morning of the 31st the entire ocean, with the exception of a narrow belt along the American coast, was covered by high pressure.

## OCEAN GALES AND STORMS, OCTOBER, 1930

| Vessel | Voyage | | Position at time of lowest barometer | | Gale began | Time of lowest barometer | Gale ended | Lowest barometer | Direction of wind when gale began | Direction and force of wind at time of lowest barometer | Direction of wind when gale ended | Highest force of wind and direction | Shifts of wind near time of lowest barometer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | From— | To— | Latitude | Longitude | | | | | | | | | |
| **NORTH ATLANTIC OCEAN** | | | ° ′ | ° ′ | | | | *Inches* | | | | | |
| Gulfhawk, Am. M. S. | New York | Las Piedras | 31 00 N | 75 00 W | Oct. 1 | 9a., Oct. 1 | Oct. 3 | 29.69 | NNE. | NNE, 6 | NE. | NNE, 10 | NNE-NE. |
| Excellency, Am. S. S. | Casa Blanca | New York | 36 45 N | 65 55 W | do | Mdt., 1 | do | 29.66 | NE. | NE, 9 | NE. | NE, 9 | Steady. |
| Viborg, Dan. S. S. | San Pedro de Macoris. | St. John, N. B. | 38 11 N | 67 30 W | Oct. 2 | 1 p., 3 | Oct. 4 | 29.49 | N. | NE, — | NE. | NNE, 10 | N-NE. |
| New Brighton, Br. S. S. | New York | W. Africa | 39 50 N | 61 22 W | Oct. 3 | Mdt., 4 | Oct. 5 | 29.27 | E. | SSE, 12 | WSW. | SSE, 12 | E-S-WSW. |
| Europa, Ger. S. S. | do | Cherbourg | 40 35 N | 64 30 W | Oct. 4 | 10 p., 4 | do | 29.14 | N. | NW, 12 | W. | NW, 12 | N-NW-W. |
| Yselhaven, Du. S. S. | Bremen | Norfolk | 41 44 N | 61 50 W | do | 6 a., 5 | do | 29.00 | ENE. | SW, 12 | W. | SW, 12 | ENE-SW-W. |
| Rotterdam, Du. S. S. | Rotterdam | New York | 49 22 N | 24 27 W | Oct. 7 | 8 a., 7 | Oct. 7 | 29.60 | W. | WNW, 9 | NW. | —, 9 | WSW-NNW. |
| Viborg, Dan. S. S. | San Pedro de Macoris. | St. John, N. B. | 38 11 N | 67 30 W | do | 6 p., 8 | Oct. 11 | 29.63 | N. | NE, — | NE. | NNE, 10 | N-NE. |
| Cranford, Am. S. S. | New Orleans | Havre | 40 05 N | 55 35 W | Oct. 8 | 2 p., 9 | Oct. 9 | 29.60 | E. | E, 9 | ESE. | E, 9 | E-ESE. |
| Gonzenheim, Ger. S. S. | Newcastle | Baltimore | 48 59 N | 8 54 W | Oct. 10 | 1 p., 10 | Oct. 11 | 29.32 | SSW. | SSW, 10 | WNW. | SSW, 10 | SSW-NW. |
| Samala, Br. S. S. | Jamaica | Liverpool | 39 20 N | 49 37 W | Oct. 11 | 3 p., 11 | Oct. 14 | 29.36 | WNW. | WNW, 8 | NNW. | WNW, 11 | SSW-WNW. |
| Cranford, Am. S. S. | New Orleans | Havre | 42 35 N | 46 20 W | do | 8 p., 11 | do | 29.10 | NE. | NE, 6 | NNW. | NW, 10 | NW-NNW. |
| Lubrafol, Belg. M. S. | Panama | Antwerp | 43 09 N | 33 01 W | do | Noon, 12 | Oct. 13 | 29.18 | S. | SW, 11 | NW. | SW, 11 | SW-W-NW. |
| Dresden, Ger. S. S. | Cobh | New York | 50 26 N | 21 55 W | Oct. 13 | 11 a., 13 | do | 28.85 | SSW. | SSW, 10 | SSW. | SSW, 10 | SSW-WSW. |
| West Eldara, Am. S. S. | New York | Antwerp | 45 40 N | 40 39 W | Oct. 12 | 4 p., 13 | Oct. 15 | 29.17 | N. | WNW, 10 | NW. | WNW, 10 | NW-WNW. |
| Dunrobin, Br. S. S. | Huelva, Spain. | New York | 35 50 N | 25 40 W | Oct. 13 | 11 a, 14 | Oct. 14 | 29.54 | SW. | SW, — | NW. | SW, 9 | SW-NW. |
| Emile Francique, Belg. S. S. | Antwerp | do | 50 50 N | 24 25 W | do | Noon, 14 | Oct. 16 | 28.90 | S. | SW, 5 | NW. | NW, 10 | SW-W-NW. |
| Jalapa, Am. S. S. | Liverpool | Boston | 54 20 N | 29 00 W | do | —, 14 | Oct. 17 | 28.34 | ENE. | N, 11 | W. | NW, 12 | NNE-N. |
| Australien, Dan. M. S. | St. Thomas | Hamburg | 42 17 N | 24 17 W | Oct. 16 | 4 p., 16 | do | 29.66 | W. | NW, 9 | NW. | NW, 9 | Steady. |
| Liberty Glo, Am. S. S. | Savannah | Bremen | 48 56 N | 18 38 W | Oct. 18 | 11 p., 18 | Oct. 19 | 29.07 | S. | S, 10 | WNW. | —, 10 | SSE-S-WNW. |
| Sonora, Fr. S. S. | Houston | Havre | 46 44 N | 16 45 W | do | 4 a., 19 | do | 29.25 | SW. | WNW, 10 | NW. | WNW, 10 | SW-WNW. |
| Wytheville, Am. S. S. | Antwerp | New York | 50 40 N | 14 10 W | do | 6 a., 19 | do | 29.98 | S. | SSW, 10 | WNW. | S, 10 | S-SW-WNW. |
| Nubian, Br. S. S. | Nassau | Vera Cruz | 20 02 N | 94 42 W | do | 4 a., 19 | Oct. 20 | 29.45 | SW. | WSW, — | NE. | WSW, 10 | SW-W-N. |
| Cameronia, Br. S. S. | Glasgow | New York | 55 33 N | 11 51 W | Oct. 19 | 11 a., 19 | do | 28.32 | SE. | SW, 11 | W. | SW, 11 | SE-S-W. |
| Sulaco, Br. S. S. | Jamaica | Liverpool | 34 09 N | 59 10 W | Oct. 23 | 9 p., 23 | Oct. 23 | 29.71 | NNW. | NNW, 8 | NNW. | NNW, 9 | W-NW-NNW. |
| Limon, Am. S. S. | Tela | Boston | 34 22 N | 75 25 W | Oct. 24 | Noon, 24 | Oct. 26 | 29.75 | NNW. | NNW, 6 | NNW. | NNW, 10 | Steady. |
| Explorer, Am. S. S. | Morocco | New York | 41 28 N | 62 03 W | Oct. 25 | 4 a., 25 | Oct. 27 | 29.26 | SE. | N, 7 | NNW. | NW, 10 | NW-N-NW. |
| Dresden, Ger. S. S. | New York | Cobh | 41 24 N | 60 12 W | do | 8 a., 25 | Oct. 25 | 29.11 | SE. | SE, 9 | S. | SE, 10 | ESE-W. |
| K. R. Kingsbury, Am. S. S. | Cristobal, C. Z. | Philadelphia | 36 06 N | 74 41 W | Oct. 24 | —, 25 | Oct. 26 | 29.66 | SSE. | WNW, 9 | NW. | NW, 10 | NW-WNW. NW. |
| Dunrobin, Br. S. S. | Huelva, Spain. | New York | 37 40 N | 68 29 W | Oct. 25 | 3 a., 26 | Oct. 27 | 29.38 | NW. | NW, 8 | WNW. | NW, 10 | NNW-NNE. |
| Silveryew, Br. M. S. | Port Said | Baltimore | 36 50 N | 60 30 W | do | 4 p., 26 | do | 29.54 | S. | WSW, — | NNW. | W, 10 | S-WSW-NNW. |
| De Grasse, Fr. S. S. | Havre | New York | 44 00 N | 47 00 W | Oct. 27 | 6 p., 27 | Oct. 28 | 29.39 | SSW. | SW, 8 | WNW. | WNW, 9 | SSW-WNW. |
| Emanuel Nobel, Belg. S. S. | Antwerp | Philadelphia | 45 58 N | 41 51 W | do | Mdt., 28 | Oct. 29 | 29.46 | SSW. | SSW, 9 | NW. | W, 10 | SW-W. |
| Dakarian, Br. S. S. | Liverpool | Boston | 49 55 N | 41 44 W | Oct. 31 | Mdt., 31 | Nov. 1 | 29.58 | SW. | W, 9 | WNW. | W, — | SW-WSW-W. |
| **NORTH PACIFIC OCEAN** | | | | | | | | | | | | | |
| Melville Dollar, Am. S. S. | Tabaco, P. I. | Los Angeles | 23 22 N | 144 22 E | Oct. 1 | —, 2 | Oct. 3 | 29.32 | NE. | SSW, 10 | SSE. | SSW, 10 | W-S-SSE. |
| Singalese Prince, Br. M. S. | San Pedro | Yokohama | 34 17 N | 171 11 W | do | 2 p., 2 | do | 29.36 | SSW. | W, 9 | NE. | W, 9 | W-WNW. |
| Kuma Maru, Jap. S. S. | Yokohama | San Francisco | 46 57 N | 153 13 W | Oct. 2 | Noon, 3 | do | 29.41 | E. | E, 9 | SSW. | E, 9 | E-S. |
| Columbia Maru, Jap. M. S. | Vancouver | Yokohama | 39 52 N | 146 30 E | Oct. 3 | 4 a., 4 | Oct. 4 | 29.40 | SE. | WSW, 3 | NNW. | SE, 9 | S-WSW-W. |
| Paris Maru, Jap. S. S. | Yokohama | Seattle | 46 34 N | 167 16 E | do | 8 a., 5 | Oct. 5 | 28.92 | SE. | SSW, 10 | SW. | SSW, 10 | 6 pts. |
| City of Vancouver, Can. S. S. | do | Vancouver | 42 42 N | 157 24 E | do | 10 p., 4 | do | 28.68 | SE. | S, 10 | SW. | SW, 10 | SSE-S-SW. |
| Tamaha, Br. S. S. | Shanghai | San Pedro | 40 23 N | 156 46 E | Oct. 4 | 8 p., 4 | do | 29.27 | SSW. | SSW, 8 | WSW. | W, 9 | SSW-SW. |
| Petricola, Br. S. S. | Singapore | Yokohama | 21 25 N | 120 50 E | Oct. 8 | 8 p., 8 | Oct. 12 | 29.82 | NE. | NE, 6 | NE. | NNE, 8 | Steady. |
| Kentucky, Am. S. S. | Ternate | San Francisco | 39 26 N | 146 24 W | Oct. 14 | Noon, 15 | Oct. 15 | 29.77 | S. | S, 7 | SSW. | S, 9 | S-SSW. |
| Emp. of Japan, Br. S. S. | Vancouver | Honolulu | 50 30 N | 143 00 W | Oct. 15 | 4 p., 15 | Oct. 16 | 29.40 | ESE. | ESE, 8 | — | ESE, 9 | ESE-SSW. |
| Illinois, Am. S. S. | Portland | Yokohama | 45 52 N | 160 55 E | Oct. 13 | Noon, 16 | Oct. 18 | 29.48 | NNW. | WNW, 7 | NNW. | NW, 8 | WSW-NNW. |
| Hawaii Maru, Jap. S. S. | Yokohama | Victoria | 49 07 N | 179 26 W | Oct. 21 | Mdt., 21 | Oct. 22 | 29.21 | SSE. | SE, 9 | WSW. | SE, 9 | SSE-SE-WSW. |
| Olympia, Am. S. S. | Tacoma | Yokohama | 46 27 N | 161 40 E | do | Noon, 21 | Oct. 23 | 29.43 | S. | S, 6 | N. | SE, 9 | SE-NW. |
| Do | do | do | 37 27 N | 144 02 E | Oct. 26 | 4 p., 26 | Oct. 27 | 29.02 | W. | NNW, 12 | N. | NNW, 12 | Steady. |
| Kinkassan Maru, Jap. S. S. | Muroran | Portland | 47 36 N | 130 54 W | Oct. 21 | 6 p., 22 | Oct. 23 | 29.52 | SE. | SSE, 8 | WSW. | SSE, 8 | SE-SW. |
| Toba Maru, Jap. S. S. | Yokohama | San Francisco | 37 41 N | 164 29 E | Oct. 25 | 3 a., 27 | Oct. 27 | 29.74 | ESE. | SE, 8 | SSW. | SE, 9 | 5 pts. |
| Chief Capilano, Br. S. S. | Shanghai | Vancouver | 41 50 N | 147 40 E | Oct. 26 | 10 a., 27 | Oct. 28 | 29.00 | E. | N, 10 | NNW. | N, 11 | NNE-N. |
| Kinai Maru, Jap. S. S. | Yokohama | Los Angeles | 40 05 N | 150 22 E | Oct. 25 | —, 27 | Oct. 30 | 28.75 | NE. | SSW, 11 | NNW. | SSW, 11 | S-SSW-SW. |
| Pres. Pierce, Am. S. S. | Victoria | Yokohama | 44 43 N | 158 52 E | Oct. 27 | —, 28 | Oct. 29 | 29.11 | SE. | SSW, 7 | ESE. | NW, 9 | S-SSW-NW. |
| Do | do | do | 34 50 N | 140 11 E | Oct. 30 | —, 31 | Oct. 31 | 29.55 | NE. | NE, 12 | — | NE, 12 | NE-NW. |
| Hakutatsu Maru, Jap. S. S. | Karatsu | Vancouver | 50 05 N | 134 15 W | Oct. 29 | Mdt., 29 | Oct. 30 | 29.29 | S. | S, 9 | W. | S, 9 | S-SSW. |
| Akibasan Maru, Jap. S. S. | Yokohama | San Francisco | 44 57 N | 165 28 E | Oct. 28 | 4 p., 28 | Oct. 31 | 29.27 | S. | SW, 8 | NNW. | WNW, 10 | SSW-SW-W. |
| Golden Tide, Am. S. S. | Hong Kong | do | 37 47 N | 146 14 E | Oct. 29 | 4 p., 31 | Nov. 1 | 29.18 | NNW. | E, 12 | — | E, 12 | E-NE. |
| Arizona Maru, Jap. S. S. | Yokohama | Vancouver | 36 19 N | 142 44 E | Oct. 30 | Noon, 31 | do | 29.28 | ENE. | NNE, 10 | NE. | NNE, 10 | NE-NNE. |
| **Mexican West Coast Gales** | | | | | | | | | | | | | |
| Solana, Am. S. S. | Balboa | San Francisco | 16 40 N | 100 40 W | Oct. 3 | 4 a., 3 | Oct. 3 | 29.65 | NW. | NW, 7 | NW. | NW, 8 | NW-W. |
| Santa Isabel, Am. S. S. | San Francisco | Balboa | 21 13 N | 109 00 W | do | 6 a., 4 | Oct. 4 | 28.20 | E. | NNW, 12 | W. | NNW, 12 | N-NNW-NW. |
| Wind Rush, Am. S. S. | Colon | San Pedro | 21 23 N | 108 41 W | Oct. 4 | 10 a., 4 | Oct. 5 | 28.17 | S. | Calm | NNW. | SW, 12 | SW-O-W. |
| Viking Star, Br. S. S. | Balboa | Los Angeles | 21 41 N | 108 27 W | do | 1 p., 4 | do | 27.72 | SW. | Calm | W. | NW, 12 | S-O-NW. |
| Ecuador, Am. S. S. | New York | San Francisco | 22 35 N | 106 35 W | Oct. 5 | 5 p., 5 | do | 28.64 | SSE. | SE, 12 | W. | NE, 12 | SE-NE. |
| Cambral, Am. S. S. | Panama | do | 9 55 N | 86 45 W | Oct. 6 | 2 a., 6 | Oct. 6 | 29.83 | W. | W, 8 | W. | W, 8 | Steady. |
| King Edwin, Br. M. S. | do | Vancouver | 15 16 N | 99 46 W | Oct. 9 | 9 a., 10 | Oct. 10 | 29.16 | SW. | E, 5 | N. | E, 12 | S-E-NE. |
| Buffalo Bridge, Am. S. S. | Balboa | San Pedro | [1] 16 00 N | [1] 99 00 W | Oct. 10 | 2 a., 11 | Oct. 11 | 29.30 | SE. | SE, 12 | SW. | SE, 12 | SE-SW. |
| Saramacca, Am. S. S. | San Pedro | Balboa | 16 06 N | 99 16 W | do | 10 p., 10 | do | 29.00 | NE. | S, 12 | SW. | S, 12 | NE-S. |
| Anniston City, Am. S. S. | New York | San Diego | 15 47 N | 100 50 W | do | 3 a., 10 | do | 29.62 | SW. | SSW, 9 | SSE. | SSW, 9 | SW-SSE. |
| Shikisan Maru, Jap. M. S. | Brentwood, B. C. | Liverpool | 18 40 N | 104 48 W | Oct. 17 | 8 p., 17 | Oct. 18 | 29.62 | NW. | SW, 9 | SW. | SW, 9 | NW-SW. |
| American, Am. S. S. | Balboa | Los Angeles | 17 52 N | 103 38 W | do | 3 p., 17 | do | 29.31 | SSE. | S, 9 | S. | S, 9 | SSE-S. |
| Iowan, Am. S. S. | Los Angeles | Balboa | 19 30 N | 105 23 W | do | 11 p., 17 | do | 29.60 | NE. | S, 10 | SW. | S, 10 | NE-S. |
| Arizona, Fr. S. S. | San Pedro | do | 18 24 N | 104 47 W | do | 1 a., 18 | do | 29.04 | NW. | Calm | SSW. | WSW, 10 | SSW-O-SSW. |
| Nebraskan, Am. S. S. | Los Angeles | New York | 14 44 N | 97 14 W | Oct. 30 | 5 p., 30 | Nov. 1 | 29.91 | NE. | — | NNW. | NE, 10 | N-NNE. |

[1] Approximate.

## NORTH PACIFIC OCEAN

By WILLIS E. HURD

During October, 1930, the condition of the atmospheric pressure over most of the upper half of the North Pacific Ocean underwent considerable average change. For several months the anticyclone common to middle latitudes had extended much farther north than usual, even overruning the Aleutian region and the lower waters of the Bering Sea.. In September the Aleutian LOW succeeded in organizing and in penetrating the upper part of the Gulf of Alaska, and in October it spread from the central Gulf westward, well across the island chain and adjacent waters, toward the Asiatic coast. In average pressure, however, it was still above the normal for the month, although the mean readings at Kodiak, Dutch Harbor, and St. Paul were below 29.80 inches. The North Pacific anticyclone retreated mostly into middle latitudes in October, except that its eastern extremity lay off the American coast between northern California and middle British Columbia. The departures from average barometric pressure were below normal only over southern California and the lower waters of the Pacific, as shown by the stations at San Diego, Honolulu, and Midway Island.

The following table gives barometric data for several island and coast stations in west longitudes, including Point Barrow on the Arctic Ocean.

TABLE 1.—*Averages, departures, and extremes of barometric pressure at sea level at indicated hours, North Pacific Ocean and adjacent waters, October, 1930.*

| Stations | Average pressure | Departure from normal | Highest | Date | Lowest | Date |
|---|---|---|---|---|---|---|
| | *Inches* | *Inch* | *Inches* | | *Inches* | |
| Point Barrow [1,2] | 30.11 | | 30.60 | 14th | 29.60 | 19th. |
| Dutch Harbor [1] | 29.77 | +0.08 | 30.22 | 12th | 29.00 | 24th. |
| St. Paul [1,2] | 29.74 | +0.08 | 30.26 | 12th | 29.02 | 24th. |
| Kodiak [1,2] | 29.73 | +0.14 | 30.36 | 13th | 28.96 | 25th. |
| Midway Island [1] | 30.03 | −0.02 | 30.24 | 27th [3] | 29.76 | 2d. |
| Honolulu [4] | 29.97 | −0.03 | 30.13 | 23d | 29.73 | 4th. |
| Juneau [4] | 29.87 | +0.01 | 30.41 | 15th | 29.19 | 23d. |
| Tatoosh Island [4,5] | 30.03 | 0.00 | 30.47 | 27th | 29.45 | 7th. |
| San Francisco [4,5] | 29.97 | +0.03 | 30.24 | 30th | 29.68 | 7th. |
| San Diego [4,5] | 29.90 | −0.03 | 30.08 | 31st | 29.69 | 6th. |

[1] P. m. observations only.
[2] For 30 days.
[3] And on the 28th.
[4] A. m. and p. m. observations.
[5] Corrected to 24-hour mean.

While there was an increase in the number of days with gales in October, as compared with September, yet over the main body of the ocean the degree of storminess was somewhat less intense, except in coastal localities, than in the preceding month. In Japanese waters, however, especially along the south and east coasts, and as far to the eastward of Honshu as longitude 155° E., storms of great severity occurred from the 26th to the 31st of the month. During this period storm to hurricane velocities were reported by several vessels, and on the 27th a barometer reading as low as 28.75 inches was noted on board the Japanese steamship *Kinai Maru*, near 40° N., 150 E. The first of the two cyclones occasioning these heavy conditions originated in the Eastern Sea about the 24th, and by the 26th was causing gales of force 12 at some distance east of Yokohama. On the 27th the major gale area, with wind forces up to 11, lay southeast of the island of Yezo, and on the 28th, with diminished energy, lay southeast of the Kuril Islands. The second cyclone appeared as a slight depression over eastern China on the 29th. It followed nearly the course of its predecessor, except that it came into closer proximity to the Japanese coast, strongly influencing the southeastern islands of the archipelago on the 30th, and causing hurricane winds south and east of Honshu on the 31st, with barometer down nearly to 29 inches. The American steamship *Golden Tide* reported that the seas on this date were so heavy that her roll amounted to 50°.

Of the purely extratropical gales not exceeding 10 in force, as reported, one occurred on the 22d, near 35° N., 145° W., on the lower edge of a Gulf of Alaska depression, and another was experienced near 46° N., 173° E., on the 29th. Gales of force 8 and 9 were fairly well distributed as to date over the ocean, but were about two times more frequent along the middle and upper routes over the western than over the eastern half of the ocean. The deepest extratropical cyclone of the month in upper waters appeared over the Bering Sea and reached its greatest intensity on the 24th and 25th, Kodiak having a barometer reading of 28.96 inches on the latter date. The storm moved slowly eastward into the Gulf of Alaska, where it remained as a fluctuating disturbance of reduced intensity until the end of the month. Few gales, however, as far as known, and those not exceeding 9 in force, accompanied its prevalence.

In the Asiatic Tropics a typhoon of some severity caused fresh to whole gales on the 1st and 2d south of the Ogasawara Islands.

From the 8th to the 12th strong northeast monsoon winds prevailed in the Balintang Channel and off the China coast, frequently attaining gale force. During a part of the time the monsoon was strengthened by the presence of a LOW east of Luzon, which added to the gradient between its center and the powerful anticyclone then existing over southeastern Asia.

In the American Tropics the weather was frequently disturbed, cyclones, northers, and squalls of various types contributing to the unrest. At least three cyclones occurred, of which two are known to have acquired hurricane wind forces.

First and most intense of the cyclonic storms was that which apparently originated near the Revillagigedo Islands or slightly to the southward about the 3d. Moving northeastward into the entrance to the Gulf of California, where it became extraordinarily severe and slow of progression on the 4th and 5th, it entered the Mexican coast north of Mazatlan. Overland it diminished in energy to little more than a mere depression, but acquired greatly accelerated speed, and died out in Arkansas on the 7th. The storm was reported as one of the fiercest on record in the Gulf of California, and several steamships were dangerously involved in its hurricane winds. Among those sustaining considerable damage were the American steamships *Ecuador*, *Santa Isabel*, and *Wind Rush*, the British steamships *Paris City* and *Viking Star*, and the British motorship *Javanese Prince*. The cost of the repairs to the *Ecuador* was estimated at $10,000. The *Javanese Prince*, in addition to structural losses sustained by the vessel, had a damaged cargo resulting from shifting in the unusually precipitous seas. The *Viking Star* specifically referred to the "terrific list" of the vessel, which put the engine out of action owing to inability to fire.

The *Viking Star* also reported a barometric reading of 27.72 inches at 12:45 p. m. of the 4th, while in the calm center of the storm, in 21° 41′ N., 108° 27′ W. This reading is the lowest of record for any hurricane occurring in Mexican west coast waters. The *Wind Rush* reported that from 9 to 10 a. m. of the 4th, in 21° 23′ N., 018° 41′ W., "we were in a calm spot with no wind and smooth

sea, and with the sun shining, lowest barometer 28.17 inches." This is the second instance of the clear eye of the storm being observed in a cyclone in these waters, the earlier instance being reported by the American destroyer *Noa*, at practically the same spot, during the hurricane of June 10, 1930. It also gives one of the few instances on record of smooth seas in the central calm. After leaving the eye, the *Wind Rush* had generally rising barometer for nearly 24 hours, accompanied by storm winds, but from 9 a. m. to 12:30 p. m. of the 5th, during which time the vessel drifted with engine stopped, the barometer again fell a half inch, with renewal of hurricane velocities, in 22° 40′ N., 107° 26′ W. This indicated, in connection with her southeasterly winds at this time, that the hurricane had progressed but little since noon of the preceding day, and that in drifting she had kept just ahead of the storm center for hours. The *Viking Star* had a similar experience with reference to the seemingly abnormal change of the winds.

While this cyclone was gathering on the 3d, it is evident from the reports of several other vessels farther south on the same date that the weather was also disturbed between Salina Cruz and Acapulco, moderate to fresh gales being encountered off the coast, with lowest barometer read at 29.65 inches.

The second hurricane was that of the 9th to 11th west of the Gulf of Tehuantepec and up the coast to about as far as Acapulco. The American steamships *Buffalo Bridge* and *Saramacca*, and the British motorship *King Edwin* encountered hurricane velocities variously in this storm from north, northeast, east, southeast, and south. The lowest barometer was 29 inches, read on board the *Saramacca* at 10.15 p. m. of the 10th, in 16° 06′ N., 99° 16′ W.

The third cyclone was that of the 16th to 18th between Acapulco and Cape Corrientes. The storm caused strong to whole gales along a considerable stretch of the coast, and after leaving the vicinity of the cape, advanced inland and died out on the 20th in the Bay of Campeche. The lowest recorded barometer was 29.31 inches, reported by the American steamship *American*, in 17° 52′ N., 103° 38′ W., on the 17th.

Severe squalls occurred on the 4th in Panama Bay, and on the 6th off the coast of Costa Rica. Northers of moderate to fresh gale force occurred over or near the Gulf of Tehuantepec on the 2d, and of whole gale force on the 31st, this strong norther beginning on the 30th and continuing until about the 4th of November. Moderate southerly gales, accompanied by a slight barometric drop, blew near 8° N., 105° to 111° W., on the 9thand 10th.

At Honolulu the prevailing wind was from the east, with a maximum velocity of 24 miles an hour from the east on the 23d.

Fog lessened materially since September over most of the northern routes in both east and west longitudes. It occurred on about five days south of the central Aleutians, and on 10 to 12 days at scattered points south of the Gulf of Alaska. Off the American coast, however, fog showed an increase in frequency over that of September, being reported, at the maximum, on about 12 days off central California, and on about 10 days off the coast of Washington.

# CLIMATOLOGICAL TABLES[1]

## CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

*Condensed climatological summary of temperature and precipitation by sections, October, 1930*

[For description of tables and charts, see REVIEW, January, 1930, p. 37]

| Section | Temperature | | | | | | | | Precipitation | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Section average | Departure from the normal | Monthly extremes | | | | | | Section average | Departure from the normal | Greatest monthly | | Least monthly | |
| | | | Station | Highest | Date | Station | Lowest | Date | | | Station | Amount | Station | Amount |
| | ° F. | ° F. | | ° F. | | | ° F. | | In. | In. | | In. | | In. |
| Alabama | 62.5 | −1.9 | 3 stations | 88 | 19 | Valley Head | 23 | 31 | 2.72 | +0.10 | Brewton (near) | 7.39 | Centerville | 0.81 |
| Arizona | 61.5 | −1.4 | Le Sage | 105 | 8 | Alpine | 10 | 29 | 0.35 | −0.53 | Seligman | 1.45 | 9 stations | 0.00 |
| Arkansas | 60.1 | −2.1 | 2 stations | 92 | 19 | Dutton | 17 | 31 | 4.89 | +1.92 | Highland | 8.45 | Marianna | 1.49 |
| California | 59.1 | −0.7 | Greenland Ranch | 106 | 7 | 2 stations | 11 | 125 | 0.38 | −0.84 | Crescent City | 2.36 | 25 stations | 0.00 |
| Colorado | 45.9 | −0.4 | 2 stations | 90 | 19 | Crested Butte | −5 | 27 | 0.97 | −0.32 | Lamar | 5.22 | Del Norte | 0.00 |
| Florida | 71.0 | −2.0 | Tarpon Springs | 94 | 17 | 2 stations | 35 | 126 | 2.70 | −1.62 | Chapman Field Garden. | 13.37 | Tarpon Springs | 0.39 |
| Georgia | 62.2 | −2.4 | 2 stations | 91 | 17 | Clayton | 24 | 122 | 1.67 | −1.09 | Columbus | 4.21 | Hazlehurst | 0.08 |
| Idaho | 45.0 | −1.7 | 4 stations | 81 | 13 | Obsidian | 6 | 28 | 1.63 | +0.15 | Grays Lake | 3.99 | Glenns Ferry | 0.18 |
| Illinois | 53.5 | −1.7 | Mount Carmel | 90 | 11 | 3 stations | 16 | 120 | 2.23 | −0.40 | Marengo | 4.17 | Harrisburg | 0.47 |
| Indiana | 52.8 | −1.7 | Edwardsport | 91 | 14 | Delphi | 15 | 22 | 1.54 | −1.15 | Decker | 3.31 | Mount Vernon | 0.66 |
| Iowa | 50.7 | −1.1 | Waterloo | 95 | 12 | Webster City | 9 | 21 | 2.08 | −0.35 | Fairport | 4.21 | Logan | 0.71 |
| Kansas | 55.0 | −2.0 | Medicine Lodge | 94 | 9 | Oketo | 13 | 31 | 3.63 | +1.72 | Richfield | 8.90 | Oketo | 0.55 |
| Kentucky | 55.9 | −2.3 | Bowling Green | 94 | 12 | 2 stations | 16 | 22 | 1.34 | −1.43 | Greenville | 2.78 | Cynthiana | 0.44 |
| Louisiana | 67.2 | −0.8 | Cheneyville | 93 | 8 | do | 27 | 31 | 4.62 | +1.32 | Monroe | 8.80 | St. Joseph | 1.48 |
| Maryland-Delaware | 54.1 | −2.2 | Cumberland, Md | 89 | 11 | Oakland, Md | 7 | 22 | 0.82 | −2.04 | Public Landing, Md. | 2.29 | 2 stations | T. |
| Michigan | 47.8 | −1.2 | Coldwater | 88 | 12 | Wolverine | 7 | 25 | 1.92 | −0.77 | Painesdale | 3.83 | Lapeer | 0.42 |
| Minnesota | 44.5 | −1.1 | New Ulm | 89 | 9 | 4 stations | 4 | 120 | 1.48 | −0.37 | Pigeon River Bridge | 4.59 | Gonvick | 0.14 |
| Mississippi | 63.6 | −1.2 | Poplarville | 91 | 9 | do | 26 | 31 | 3.12 | +0.53 | Collins | 5.52 | Water Valley | 0.90 |
| Missouri | 55.3 | −2.1 | 2 stations | 92 | 19 | Chillicothe | 11 | 31 | 3.06 | +0.17 | Birchtree | 7.09 | Macon | 0.48 |
| Montana | 40.0 | −4.1 | Belton | 80 | 1 | 2 stations | −5 | 17 | 1.46 | +0.45 | Belton | 5.64 | Savage | 0.21 |
| Nebraska | 50.5 | −0.6 | Tekamah | 94 | 10 | Arthur | 9 | 30 | 2.67 | +1.07 | Hasley | 6.82 | Table Rock | 0.23 |
| Nevada | 48.9 | −1.7 | Logandale | 94 | 6 | Zorra Vista Ranch | 10 | 126 | 0.62 | −0.03 | Lamoille (near) | 2.50 | 2 stations | 0.00 |
| New England | 49.0 | −0.4 | 3 stations | 92 | 13 | 2 stations | 15 | 23 | 2.96 | −0.58 | Blue Hill, Mass | 6.22 | Fort Kent, Me | 0.77 |
| New Jersey | 52.5 | −2.3 | Flemington | 89 | 13 | Belleplain | 12 | 23 | 1.95 | −1.45 | Hammonton | 3.70 | Boonton | 0.93 |
| New Mexico | 53.2 | 0.0 | Richland | 93 | 9 | Gavilan | 4 | 27 | 2.12 | +0.78 | Porter | 11.95 | 5 stations | 0.00 |
| New York | 48.8 | −1.1 | Troy | 86 | 13 | Jeffersonville | 15 | 121 | 1.53 | −1.80 | Philadelphia | 6.80 | Haskinville | 0.28 |
| North Carolina | 56.7 | −3.4 | Goldsboro | 92 | 17 | Mount Mitchell | 10 | 31 | 2.18 | −1.12 | Elizabethtown | 6.66 | Marion | 0.80 |
| North Dakota | 40.8 | −3.0 | Wahpeton | 86 | 11 | Beach | 0 | 17 | 1.81 | +0.81 | Powers Lake | 3.49 | Power | 0.40 |
| Ohio | 51.1 | −2.8 | 2 stations | 90 | 111 | 2 stations | 12 | 22 | 1.32 | −1.35 | Hiram | 3.52 | Wilmington | 0.04 |
| Oklahoma | 60.4 | −1.2 | Alva | 96 | 9 | Smithville | 22 | 31 | 4.13 | +1.09 | Lawton | 10.85 | Beaver | 1.05 |
| Oregon | 48.6 | −1.5 | Madras | 86 | 5 | Lake | 7 | 29 | 1.64 | −0.61 | Headworks | 8.40 | Paisley | 0.12 |
| Pennsylvania | 50.8 | −1.6 | Brookville | 93 | 15 | Somerset | 9 | 22 | 0.99 | −2.19 | Westford | 3.33 | Harrisburg (Weather Bureau). | 0.11 |
| South Carolina | 60.5 | −3.1 | 3 stations | 88 | 16 | Santuck | 25 | 26 | 2.18 | −0.84 | Society Hill | 5.07 | Spartanburg | 0.75 |
| South Dakota | 46.1 | −2.5 | Winner | 92 | 10 | 5 stations | 6 | 117 | 2.21 | +0.84 | Redfield | 4.78 | Hardy Ranger Station. | 0.40 |
| Tennessee | 57.5 | −1.9 | 2 stations | 89 | 14 | 2 stations | 19 | 122 | 2.64 | −0.20 | Johnsonville | 4.28 | Knoxville | 1.44 |
| Texas | 66.0 | −1.5 | Riogrande | 98 | 18 | Miami | 26 | 30 | 6.24 | +3.65 | Paint Rock | 17.00 | Clint | 0.21 |
| Utah | 47.0 | −1.8 | St. George | 89 | 7 | Woodruff | 6 | 129 | 1.17 | −0.16 | Brigham City | 3.74 | 3 stations | 0.00 |
| Virginia | 55.1 | −2.4 | Woodstock | 89 | 10 | Burkes Garden | 10 | 22 | 1.24 | −1.71 | Onley | 2.54 | Mount Weather | 0.09 |
| Washington | 46.7 | −2.4 | Lake Clealum | 88 | 4 | Mount Baker Lodge | 12 | 16 | 3.06 | −0.31 | Tatoosh Island | 14.54 | 3 stations | 0.03 |
| West Virginia | 50.5 | −4.2 | Charleston | 94 | 14 | Alpena | 8 | 22 | 0.96 | −2.16 | Bluefield | 1.89 | Moorefield | 0.08 |
| Wisconsin | 46.7 | −1.3 | 2 stations | 89 | 11 | Solon Springs | 7 | 22 | 2.29 | −0.25 | Stanley | 3.91 | Plum Island | 0.99 |
| Wyoming | 41.4 | −1.6 | Barnum | 81 | 10 | South Pass City | 2 | 16 | 1.91 | +0.73 | Crandall Creek (near). | 4.74 | Wamsutter | 0.11 |
| Alaska (September) | 42.7 | −1.1 | Tree Point | 76 | 14 | White Mountain | 7 | 20 | 3.33 | −0.13 | Port Alexander | 19.70 | Barrow | 0.05 |
| Hawaii | 74.7 | +0.9 | Kaanapali | 96 | 6 | Volcano Observatory. | 51 | 19 | 5.96 | +0.22 | Hiloa-Manawaiopuna Divide. | 22.00 | 2 stations | 0.00 |
| Porto Rico | 78.8 | +0.6 | Caguas | 96 | 27 | Guineo Reservoir | 48 | 18 | 5.73 | −2.48 | Guineo Reservoir | 15.91 | Ponce | 0.81 |

[1] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1930*

| District and station | Elevation of instruments: Barometer above sea level | Elevation of instruments: Thermometer above ground | Elevation of instruments: Anemometer above ground | Pressure: Station, reduced to mean of 24 hours | Pressure: Sea level, reduced to mean of 24 hours | Pressure: Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Temperature of the air: Departure from normal | Temperature of the air: Maximum | Temperature of the air: Date | Temperature of the air: Mean maximum | Temperature of the air: Minimum | Temperature of the air: Date | Temperature of the air: Mean minimum | Temperature of the air: Greatest daily range | Mean wet thermometer | Mean temperature of the dew-point | Mean relative humidity | Precipitation: Total | Precipitation: Departure from normal | Precipitation: Days with .01, or more | Wind: Total movement | Wind: Prevailing direction | Wind: Maximum velocity: Miles per hour | Wind: Maximum velocity: Direction | Wind: Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | ° *F.* | ° *F.* | °*F.* | | °*F.* | ° *F.* | | °*F.* | ° *F.* | ° *F.* | ° *F.* | % | *In.* | *In.* | | *Miles* | | | | | | | | *0–10* | *In.* | *In.* |
| *New England* | | | | | | | 50.9 | −0.2 | | | | | | | | | | 76 | 3.05 | −0.2 | | | | | | | | | | 5.4 | | |
| Eastport | 76 | 67 | 85 | 29.93 | 30.02 | +0.02 | 50.5 | +3.0 | 82 | 12 | 57 | 32 | 21 | 44 | 31 | 45 | 41 | 75 | 1.24 | −2.3 | 9 | 7,710 | n. | 45 | ne. | 25 | 8 | 6 | 17 | 6.6 | T. | 0.0 |
| Greenville, Me. | 1,070 | 6 | ---- | 28.88 | 30.06 | ---- | 46.4 | ---- | 83 | 13 | 55 | 24 | 21 | 38 | 32 | ---- | ---- | ---- | 2.80 | ---- | 9 | 4,114 | n. | 21 | ---- | 26 | 12 | 10 | 9 | ---- | T. | 0.0 |
| Portland, Me. | 103 | 82 | 117 | 29.93 | 30.06 | +.02 | 51.0 | +1.1 | 82 | 13 | 59 | 30 | 23 | 44 | 26 | 45 | 40 | 72 | 4.13 | +1.0 | 9 | 5,767 | n. | 36 | ne. | 25 | 15 | 4 | 12 | 4.9 | T. | 0.0 |
| Concord | 289 | 70 | 79 | 29.73 | 30.05 | .00 | 47.8 | −1.9 | 88 | 13 | 60 | 20 | 23 | 36 | 47 | ---- | ---- | ---- | 2.76 | −0.1 | 9 | 2,845 | n. | 20 | ne. | 25 | 16 | 6 | 9 | 4.3 | T. | 0.0 |
| Burlington | 403 | 11 | 48 | 29.62 | 30.07 | +.03 | 48.1 | −1.1 | 79 | 13 | 57 | 28 | 27 | 39 | 32 | ---- | ---- | ---- | 2.48 | −0.5 | 8 | 4,947 | n. | 26 | n. | 25 | 9 | 6 | 16 | 6.3 | T. | 0.0 |
| Northfield | 876 | 12 | 60 | ---- | 30.10 | +.06 | 44.5 | −1.0 | 84 | 13 | 57 | 16 | 23 | 32 | 44 | ---- | ---- | 88 | 1.10 | −1.8 | 6 | 3,570 | s. | 21 | ne. | 17 | 7 | 11 | 13 | 6.4 | 1.8 | 0.0 |
| Boston | 125 | 106 | 165 | 29.90 | 30.04 | −.01 | 53.0 | −0.6 | 87 | 13 | 60 | 34 | 21 | 46 | 29 | 47 | 43 | 74 | 5.83 | +2.7 | 10 | 5,520 | nw. | 30 | n. | 25 | 13 | 8 | 10 | 5.2 | T. | 0.0 |
| Nantucket | 12 | 14 | 90 | 29.99 | 30.00 | −.05 | 54.6 | +0.4 | 73 | 14 | 59 | 40 | 23 | 50 | 18 | 50 | 46 | 77 | 3.28 | −0.1 | 13 | 11,098 | n. | 43 | n. | 25 | 9 | 9 | 13 | 5.9 | 0.0 | 0.0 |
| Block Island | 26 | 11 | 46 | 29.99 | 30.02 | −.03 | 54.2 | −0.7 | 73 | 13 | 59 | 39 | 25 | 49 | 19 | 50 | 46 | 76 | 4.16 | +0.6 | 8 | 11,293 | n. | 50 | nw. | 25 | 12 | 8 | 11 | 5.4 | 0.0 | 0.0 |
| Providence | 160 | 215 | 251 | 29.86 | 30.04 | −.01 | 51.9 | −0.3 | 77 | 12 | 60 | 33 | 22 | 44 | 27 | 46 | 41 | 71 | 3.60 | +0.5 | 10 | 7,625 | nw. | 38 | nw. | 25 | 16 | 4 | 11 | 4.6 | 0.0 | 0.0 |
| Hartford | 159 | 122 | ---- | 29.88 | 30.06 | .00 | 51.6 | +0.4 | 84 | 13 | 62 | 29 | 21 | 42 | 36 | ---- | ---- | ---- | 2.43 | −1.1 | 10 | ---- | n. | ---- | ---- | ---- | 13 | 8 | 10 | 4.6 | T. | 0.0 |
| New Haven | 106 | 74 | 153 | 29.94 | 30.06 | .00 | 52.8 | −1.0 | 77 | 10 | 62 | 31 | 23 | 44 | 30 | 47 | 42 | 71 | 2.50 | −1.2 | 10 | 5,795 | n. | 26 | n. | 15 | 12 | 10 | 9 | 4.7 | 0.0 | 0.0 |
| *Middle Atlantic States* | | | | | | | 54.8 | −1.8 | | | | | | | | | | 69 | 1.32 | −1.7 | | | | | | | | | | 4.6 | | |
| Albany | 97 | 107 | 115 | 29.97 | 30.06 | +.02 | 51.5 | −0.6 | 81 | 13 | 61 | 27 | 23 | 42 | 33 | 45 | 41 | 77 | 1.13 | −1.6 | 8 | 3,743 | s. | 24 | nw. | 25 | 14 | 10 | 7 | 4.7 | T. | 0.0 |
| Binghamton | 871 | 10 | 84 | 29.16 | 30.11 | +.05 | 49.4 | −0.6 | 81 | 14 | 60 | 23 | 23 | 39 | 38 | ---- | ---- | ---- | 0.93 | −2.0 | 7 | 3,026 | ne. | 20 | w. | 19 | 6 | 6 | 19 | 6.9 | 0.4 | 0.0 |
| New York | 314 | 414 | 454 | 29.73 | 30.06 | .00 | 55.0 | −1.3 | 76 | 13 | 62 | 36 | 20 | 48 | 22 | 48 | 42 | 66 | 1.76 | −1.8 | 8 | 9,058 | n. | 54 | nw. | 25 | 10 | 11 | 10 | 5.3 | 0.0 | 0.0 |
| Bellefonte | 1,050 | 5 | 36 | 28.98 | 30.11 | ---- | 48.0 | ---- | 82 | 14 | 61 | 18 | 27 | 34 | 45 | 41 | 37 | 75 | 0.43 | ---- | 5 | ---- | sw. | ---- | ---- | ---- | 9 | 12 | 10 | 5.7 | T. | 0.0 |
| Harrisburg | 374 | 94 | 104 | 29.72 | 30.12 | +.04 | 53.9 | −0.9 | 80 | 14 | 63 | 30 | 21 | 44 | 31 | 46 | 40 | 64 | 0.11 | −2.8 | 6 | 3,650 | nw. | 24 | sw. | 19 | 13 | 12 | 6 | 4.5 | T. | 0.0 |
| Philadelphia | 114 | 123 | 367 | 29.96 | 30.09 | +.02 | 56.7 | −1.1 | 81 | 13 | 65 | 37 | 21 | 49 | 27 | 48 | 42 | 62 | 1.74 | −1.1 | 7 | 8,187 | n. | 46 | nw. | 25 | 17 | 6 | 8 | 4.0 | 0.0 | 0.0 |
| Reading | 325 | 81 | 98 | 29.74 | 30.10 | ---- | 54.0 | −0.7 | 81 | 17 | 64 | 31 | 23 | 44 | 33 | 46 | 41 | 67 | 0.66 | −2.5 | 4 | 3,030 | nw. | 26 | w. | 17 | 13 | 10 | 8 | 4.9 | 0.0 | 0.0 |
| Scranton | 805 | 111 | 119 | 29.23 | 30.10 | +.03 | 50.6 | −1.3 | 81 | 14 | 61 | 27 | 21 | 40 | 35 | 44 | 39 | 72 | 1.34 | −1.7 | 6 | 3,586 | n. | 26 | nw. | 17 | 10 | 14 | 7 | 5.1 | T. | 0.0 |
| Atlantic City | 52 | 37 | 172 | 30.01 | 30.07 | .00 | 54.7 | −2.2 | 71 | 28 | 62 | 32 | 21 | 48 | 23 | 50 | 46 | 75 | 2.43 | −0.8 | 7 | 10,208 | nw. | 50 | nw. | 25 | 17 | 7 | 7 | 3.9 | 0.0 | 0.0 |
| Cape May | 17 | 13 | 49 | ---- | ---- | ---- | 55.2 | −4.4 | 75 | 13 | 63 | 34 | 21 | 47 | 24 | 51 | 47 | 76 | 2.46 | −0.8 | 6 | ---- | nw. | ---- | ---- | ---- | 15 | 11 | 5 | ---- | 0.0 | 0.0 |
| Sandy Hook | 22 | 10 | 55 | 30.03 | 30.05 | ---- | 55.4 | ---- | 74 | 13 | 61 | 38 | 21 | 50 | 20 | 49 | 44 | 71 | 1.89 | −1.9 | 6 | 9,602 | ne. | 44 | n. | 25 | 12 | 10 | 9 | 4.9 | 0.0 | 0.0 |
| Trenton | 190 | 159 | 183 | 29.87 | 30.07 | ---- | 54.0 | −1.6 | 80 | 13 | 63 | 31 | 21 | 45 | 29 | 47 | 41 | 67 | 2.08 | −0.7 | 8 | 6,264 | nw. | 38 | nw. | 25 | 18 | 4 | 9 | 3.9 | 0.0 | 0.0 |
| Baltimore | 123 | 100 | 215 | 29.96 | 30.10 | +.02 | 57.6 | −0.3 | 82 | 17 | 66 | 36 | 21 | 49 | 27 | 49 | 42 | 61 | 0.37 | −2.5 | 5 | 6,203 | n. | 33 | nw. | 25 | 17 | 9 | 5 | 3.8 | T. | 0.0 |
| Washington | 112 | 62 | 85 | 29.98 | 30.11 | +.03 | 56.2 | −1.2 | 84 | 17 | 66 | 31 | 21 | 46 | 34 | 47 | 41 | 64 | 0.28 | −2.6 | 4 | 3,405 | nw. | 34 | nw. | 17 | 17 | 5 | 9 | 4.4 | 0.0 | 0.0 |
| Cape Henry | 18 | 8 | 54 | 30.05 | 30.07 | ---- | 59.8 | −2.3 | 88 | 17 | 65 | 36 | 23 | 54 | 28 | 53 | 49 | 71 | 1.59 | −1.4 | 8 | 9,926 | ne. | 45 | nw. | 25 | 17 | 6 | 8 | 4.4 | 0.0 | 0.0 |
| Lynchburg | 681 | 153 | 188 | 29.38 | 30.13 | +.04 | 55.6 | −2.9 | 83 | 16 | 67 | 26 | 22 | 44 | 41 | 47 | 42 | 67 | 0.62 | −2.5 | 7 | 3,480 | w. | 30 | n. | 25 | 14 | 10 | 7 | 4.4 | T. | 0.0 |
| Norfolk | 91 | 170 | 205 | 30.00 | 30.10 | +.03 | 59.7 | −2.8 | 85 | 17 | 66 | 39 | 26 | 53 | 24 | 52 | 46 | 67 | 2.00 | −1.0 | 7 | 7,980 | ne. | 36 | nw. | 25 | 15 | 8 | 8 | 4.4 | 0.0 | 0.0 |
| Richmond | 144 | 11 | 52 | 29.96 | 30.11 | +.03 | 57.2 | −2.4 | 84 | 17 | 68 | 29 | 23 | 46 | 36 | 48 | 42 | 66 | 1.31 | −1.6 | 7 | 4,525 | ne. | 24 | n. | 25 | 16 | 11 | 4 | 3.7 | 0.0 | 0.0 |
| Wytheville | 2,304 | 49 | 55 | 27.72 | 30.12 | +.03 | 50.2 | −3.4 | 76 | 11 | 62 | 18 | 22 | 39 | 40 | 43 | 39 | 72 | 1.10 | −1.7 | 9 | 3,275 | w. | 23 | sw. | 19 | 15 | 6 | 10 | 4.5 | 0.6 | T. |
| *South Atlantic States* | | | | | | | 61.5 | −2.7 | | | | | | | | | | 71 | 1.65 | −1.6 | | | | | | | | | | 4.1 | | |
| Asheville | 2,253 | 70 | 84 | 27.76 | 30.14 | +.05 | 52.8 | −2.5 | 75 | 10 | 63 | 26 | 22 | 43 | 39 | 46 | 42 | 76 | 1.60 | −1.8 | 8 | 4,411 | se. | 25 | n. | 17 | 14 | 10 | 7 | 4.5 | T. | T. |
| Charlotte | 779 | 55 | 62 | 29.27 | 30.12 | +.04 | 59.2 | −2.5 | 83 | 16 | 69 | 34 | 26 | 49 | 30 | 51 | 46 | 70 | 1.19 | −1.8 | 8 | 2,737 | ne. | 15 | nw. | 17 | 17 | 4 | 10 | 4.1 | 0.0 | 0.0 |
| Greensboro | 886 | 5 | 56 | 29.16 | 30.12 | ---- | 55.1 | ---- | 82 | 16 | 67 | 23 | 26 | 43 | 42 | 47 | 43 | 76 | 1.10 | ---- | 8 | 4,532 | ne. | 23 | nw. | 17 | 15 | 5 | 11 | 4.2 | 0.0 | 0.0 |
| Hatteras | 11 | 5 | 50 | 30.04 | 30.05 | −.01 | 63.2 | −2.7 | 81 | 13 | 68 | 42 | 27 | 58 | 25 | 58 | 54 | 76 | 2.71 | −2.2 | 7 | 10,141 | n. | 34 | nw. | 25 | 12 | 10 | 9 | 4.8 | 0.0 | 0.0 |
| Raleigh | 376 | 103 | 110 | 29.70 | 30.10 | +.03 | 58.4 | −3.6 | 83 | 16 | 68 | 34 | 26 | 48 | 29 | 50 | 44 | 66 | 2.01 | 0.0 | 8 | 5,212 | ne. | 30 | nw. | 25 | 17 | 7 | 7 | 4.2 | 0.0 | 0.0 |
| Wilmington | 78 | 81 | 91 | 30.01 | 30.09 | +.03 | 61.2 | −4.1 | 85 | 16 | 70 | 37 | 26 | 52 | 28 | 54 | 49 | 72 | 1.86 | −1.4 | 4 | 3,901 | n. | 18 | n. | 1 | 17 | 7 | 7 | 4.1 | 0.0 | 0.0 |
| Charleston | 48 | 11 | 92 | 30.03 | 30.08 | +.02 | 64.9 | −2.9 | 86 | 16 | 72 | 45 | 31 | 57 | 20 | 58 | 53 | 72 | 0.79 | −2.5 | 4 | 6,571 | ne. | 22 | n. | 29 | 16 | 9 | 6 | 4.0 | 0.0 | 0.0 |
| Columbia, S. C. | 351 | 41 | 57 | 29.72 | 30.11 | +.04 | 61.3 | −3.0 | 84 | 17 | 72 | 38 | 26 | 51 | 33 | 53 | 46 | 65 | 1.92 | −0.6 | 5 | 3,682 | ne. | 18 | sw. | 30 | 16 | 9 | 6 | 3.6 | 0.0 | 0.0 |
| Due West | 711 | 10 | 55 | 29.37 | 30.15 | ---- | 60.0 | ---- | 84 | 17 | 71 | 33 | 25 | 49 | 35 | ---- | ---- | ---- | 0.81 | ---- | 5 | 4,974 | ne. | 26 | w. | 30 | 14 | 10 | 7 | 4.0 | 0.0 | 0.0 |
| Greenville, S. C. | 1,039 | 139 | 146 | 29.01 | 30.10 | ---- | 60.0 | −0.2 | 84 | 16 | 69 | 36 | 31 | 51 | 29 | 51 | 45 | 66 | 1.45 | −1.7 | 6 | 4,712 | ne. | 28 | n. | 24 | 15 | 10 | 6 | 3.9 | 0.0 | 0.0 |
| Augusta | 182 | 62 | 77 | 29.89 | 30.08 | +.01 | 62.7 | −2.6 | 85 | 17 | 73 | 37 | 27 | 52 | 37 | 54 | 50 | 72 | 2.16 | −0.3 | 7 | 2,877 | nw. | 15 | w. | 30 | 16 | 8 | 7 | 3.6 | 0.0 | 0.0 |
| Savannah | 65 | 150 | 194 | 30.00 | 30.07 | +.02 | 65.2 | −2.7 | 87 | 17 | 74 | 43 | 31 | 56 | 26 | 57 | 52 | 71 | 0.64 | −2.3 | 4 | 6,610 | n. | 22 | sw. | 29 | 17 | 7 | 7 | 4.0 | 0.0 | 0.0 |
| Jacksonville | 43 | 209 | 245 | 30.00 | 30.05 | +.03 | 67.8 | −3.3 | 86 | 17 | 75 | 43 | 31 | 60 | 23 | 60 | 56 | 73 | 1.57 | −2.9 | 6 | 7,181 | n. | 24 | s. | 29 | 11 | 14 | 6 | 4.8 | 0.0 | 0.0 |
| *Florida Peninsula* | | | | | | | 76.0 | −0.8 | | | | | | | | | | 76 | 4.69 | −1.2 | | | | | | | | | | 5.2 | | |
| Key West | 22 | 10 | 64 | 29.93 | 29.95 | +.01 | 78.9 | −0.2 | 89 | 17 | 84 | 67 | 31 | 74 | 15 | 72 | 70 | 77 | 7.81 | +1.8 | 11 | 6,783 | ne. | 28 | se. | 7 | 10 | 15 | 6 | 5.0 | 0.0 | 0.0 |
| Miami | 25 | 124 | 168 | 29.95 | 29.98 | .00 | 76.8 | −0.2 | 88 | 18 | 82 | 60 | 31 | 71 | 16 | 70 | 67 | 76 | 5.09 | −3.4 | 15 | 6,957 | e. | 24 | e. | 6 | 5 | 16 | 10 | 6.0 | 0.0 | 0.0 |
| Tampa | 35 | 79 | 197 | 29.98 | 30.02 | +.04 | 72.2 | −2.1 | 88 | 16 | 81 | 50 | 31 | 64 | 23 | 64 | 60 | 74 | 1.17 | −1.9 | 5 | 8,008 | ne. | 28 | e. | 12 | 13 | 8 | 10 | 4.8 | 0.0 | 0.0 |
| Titusville | 44 | 5 | ---- | 29.97 | 30.02 | ---- | 72.2 | ---- | 89 | 8 | 80 | 50 | 31 | 65 | 28 | ---- | ---- | ---- | 4.90 | ---- | 11 | ---- | ne. | ---- | ---- | ---- | 9 | 16 | 6 | 5.0 | 0.0 | 0.0 |
| *East Gulf States* | | | | | | | 64.2 | −2.3 | | | | | | | | | | 71 | 2.58 | −0.3 | | | | | | | | | | 4.0 | | |
| Atlanta | 1,173 | 190 | 216 | 28.87 | 30.12 | +.05 | 60.0 | −3.0 | 79 | 16 | 68 | 32 | 31 | 52 | 26 | 51 | 44 | 64 | 1.25 | −1.3 | 6 | 6,227 | nw. | 28 | nw. | 31 | 15 | 8 | 8 | 4.1 | 0.0 | 0.0 |
| Macon | 370 | 78 | 87 | 29.70 | 30.10 | +.04 | 61.8 | −2.7 | 85 | 17 | 73 | 35 | 26 | 50 | 35 | 53 | 48 | 67 | 2.87 | +0.5 | 4 | 3,950 | nw. | 18 | nw. | 30 | 18 | 8 | 5 | 3.2 | 0.0 | 0.0 |
| Thomasville | 273 | 49 | 103 | 29.77 | 30.07 | +.03 | 65.4 | −2.8 | 86 | 16 | 76 | 38 | 31 | 55 | 31 | 56 | 52 | 70 | 0.80 | −2.2 | 5 | 4,760 | ne. | 17 | nw. | 31 | 14 | 10 | 7 | 4.3 | 0.0 | 0.0 |
| Apalachicola | 36 | 11 | 51 | 30.01 | 30.05 | ---- | 68.2 | ---- | 85 | 9 | 76 | 43 | 31 | 61 | 23 | 61 | 57 | 73 | 0.58 | −2.6 | 4 | 6,312 | n. | 32 | se. | 6 | 16 | 9 | 6 | 3.7 | 0.0 | 0.0 |
| Pensacola | 56 | 149 | 185 | 30.00 | 30.06 | +.03 | 67.6 | −2.3 | 82 | 1 | 75 | 40 | 31 | 61 | 23 | 60 | 55 | 70 | 4.08 | −0.1 | 9 | 8,991 | ne. | 35 | se. | 7 | 16 | 4 | 11 | 4.5 | 0.0 | 0.0 |
| Anniston | 741 | 9 | 57 | 29.33 | 30.13 | +.06 | 59.2 | −3.2 | 82 | 16 | 71 | 30 | 31 | 47 | 39 | ---- | ---- | ---- | 1.37 | −1.2 | 5 | 2,661 | se. | 16 | nw. | 30 | 19 | 6 | 6 | 3.4 | 0.0 | 0.0 |
| Birmingham | 700 | 11 | 48 | 29.34 | 30.11 | +.04 | 62.3 | −2.5 | 83 | 16 | 73 | 31 | 31 | 52 | 31 | 54 | 49 | 72 | 2.55 | +0.1 | 3 | 3,884 | n. | 23 | se. | 8 | 15 | 7 | 9 | 4.0 | 0.0 | 0.0 |
| Mobile | 57 | 125 | 161 | 30.00 | 30.06 | +.02 | 67.2 | −2.1 | 86 | 8 | 76 | 40 | 31 | 59 | 27 | 60 | 57 | 76 | 4.27 | +0.7 | 8 | 6,427 | n. | 28 | n. | 17 | 16 | 4 | 11 | 4.6 | 0.0 | 0.0 |
| Montgomery | 223 | 100 | 112 | 29.86 | 30.11 | +.05 | 64.0 | −2.6 | 84 | 16 | 73 | 36 | 31 | 55 | 33 | 56 | 51 | 69 | 2.08 | −0.4 | 5 | 3,909 | ne. | 20 | n. | 31 | 17 | 5 | 9 | 3.9 | 0.0 | 0.0 |
| Corinth | 469 | 6 | ---- | ---- | ---- | ---- | 61.0 | ---- | 86 | 11 | 72 | 28 | 31 | 50 | 37 | ---- | ---- | ---- | 1.72 | ---- | 6 | ---- | se. | ---- | ---- | ---- | 6 | 19 | 6 | ---- | 0.0 | 0.0 |
| Meridian | 375 | 87 | 95 | 29.69 | 30.09 | +.03 | 62.8 | −1.5 | 84 | 16 | 73 | 33 | 31 | 52 | 36 | 56 | 52 | 75 | 4.40 | +2.0 | 6 | 3,062 | ne. | 17 | se. | 7 | 16 | 4 | 11 | 4.2 | 0.0 | 0.0 |
| Vicksburg | 247 | 65 | 73 | 29.82 | 30.10 | +.04 | 64.8 | −1.9 | 87 | 10 | 74 | 36 | 31 | 55 | 32 | 56 | 52 | 71 | 1.94 | −0.8 | 8 | 4,178 | e. | 18 | s. | 7 | 15 | 9 | 7 | 4.1 | 0.0 | 0.0 |
| New Orleans | 53 | 76 | 84 | 29.99 | 30.04 | +.01 | 70.8 | −0.2 | 86 | 16 | 78 | 46 | 31 | 64 | 20 | 63 | 59 | 74 | 4.81 | +1.5 | 9 | 4,605 | ne. | 20 | n. | 29 | 16 | 8 | 7 | 4.1 | 0.0 | 0.0 |
| *West Gulf States* | | | | | | | 66.9 | −1.0 | | | | | | | | | | 76 | 6.13 | +3.0 | | | | | | | | | | 4.9 | | |
| Shreveport | 249 | 77 | 93 | 29.80 | 30.07 | +.02 | 64.7 | −1.9 | 87 | 10 | 74 | 40 | 31 | 56 | 29 | 59 | 57 | 81 | 4.72 | +2.0 | 6 | 3,492 | e. | 18 | se. | 6 | 20 | 4 | 7 | 4.0 | 0.0 | 0.0 |
| Bentonville | 1,303 | 11 | 44 | 28.70 | 30.07 | +.02 | 56.6 | −1.4 | 85 | 9 | 67 | 23 | 31 | 46 | 31 | ---- | ---- | ---- | 4.38 | ---- | 6 | 2,705 | s. | 16 | s. | 26 | 22 | 2 | 7 | ---- | 0.0 | 0.0 |
| Fort Smith | 457 | 79 | 94 | 29.60 | 30.08 | +.03 | 61.4 | −1.4 | 89 | 9 | 71 | 33 | 31 | 52 | 31 | 53 | 48 | 69 | 2.94 | 0.0 | 6 | 4,976 | e. | 20 | e. | 6 | 13 | 8 | 10 | 4.4 | 0.0 | 0.0 |
| Little Rock | 357 | 136 | 153 | 29.72 | 30.10 | +.04 | 61.1 | −2.5 | 83 | 9 | 70 | 34 | 31 | 52 | 25 | 54 | 48 | 68 | 3.12 | +0.4 | 5 | 4,925 | e. | 24 | n. | 28 | 16 | 5 | 10 | 4.4 | 0.0 | 0.0 |
| Austin | 605 | 136 | 148 | 29.39 | 30.02 | ---- | 68.0 | −0.3 | 89 | 10 | 77 | 41 | 25 | 59 | 31 | 61 | 57 | 75 | 3.07 | +4.9 | 11 | 4,538 | e. | 33 | n. | 23 | 10 | 8 | 13 | 5.6 | 0.0 | 0.0 |
| Brownsville | 57 | 83 | 100 | 29.89 | 29.95 | ---- | 75.6 | +0.7 | 89 | 9 | 82 | 51 | 30 | 69 | 22 | 70 | 68 | 84 | 9.36 | +6.1 | 13 | 6,391 | e. | 38 | nw. | 28 | 1 | 14 | 16 | 7.0 | 0.0 | 0.0 |
| Corpus Christi | 20 | 11 | 78 | 29.96 | 29.98 | −.02 | 73.6 | +0.4 | 86 | 9 | 79 | 53 | 30 | 68 | 19 | 68 | 66 | 80 | 7.72 | +5.2 | 13 | 7,881 | se. | 34 | ne. | 28 | 7 | 8 | 16 | 6.7 | 0.0 | 0.0 |
| Dallas | 512 | 220 | 227 | 29.50 | 30.05 | ---- | 64.0 | ---- | 84 | 11 | 73 | 41 | 31 | 56 | 25 | ---- | ---- | ---- | 5.12 | +2.4 | 6 | 7,871 | e. | 27 | n. | 28 | 16 | 5 | 10 | 4.2 | 0.0 | 0.0 |
| Fort Worth | 670 | 106 | 114 | 29.33 | 30.04 | +.01 | 65.6 | −1.1 | 88 | 8 | 74 | 43 | 31 | 57 | 24 | 58 | 55 | 75 | 7.96 | +5.2 | 8 | 5,303 | se. | 21 | s. | 26 | 12 | 5 | 14 | 5.1 | 0.0 | 0.0 |
| Galveston | 54 | 106 | 114 | 29.98 | 30.04 | +.01 | 71.5 | −1.2 | 83 | 10 | 76 | 53 | 31 | 67 | 15 | 66 | 63 | 77 | 6.92 | +2.6 | 11 | 7,426 | se. | 27 | se. | 6 | 12 | 12 | 7 | 4.5 | 0.0 | 0.0 |
| Groesbeck | 461 | 11 | 56 | 29.55 | 30.04 | ---- | 65.7 | ---- | 86 | 11 | 75 | 38 | 31 | 57 | 28 | ---- | ---- | ---- | 5.92 | +1.8 | 8 | 5,845 | e. | 28 | s. | 6 | 17 | 5 | 9 | 4.3 | 0.0 | 0.0 |
| Houston | 138 | 292 | 314 | 29.88 | 30.04 | ---- | 69.7 | −0.6 | 89 | 9 | 78 | 44 | 31 | 62 | 25 | ---- | ---- | ---- | 7.57 | +3.8 | 10 | 8,421 | se. | 36 | s. | 6 | 14 | 10 | 7 | 4.6 | 0.0 | 0.0 |
| Palestine | 510 | 64 | 72 | 29.53 | 30.07 | +.04 | 65.3 | −1.9 | 86 | 11 | 74 | 37 | 31 | 56 | 27 | 58 | 55 | 77 | 6.62 | +3.3 | 8 | 4,204 | e. | 21 | se. | 6 | 16 | 5 | 10 | 4.4 | 0.0 | 0.0 |
| Port Arthur | 34 | 58 | 66 | 30.00 | 30.04 | ---- | 70.0 | ---- | 89 | 10 | 78 | 44 | 31 | 62 | 26 | 64 | 62 | 81 | 5.41 | +2.0 | 10 | 5,493 | e. | 26 | e. | 18 | 14 | 9 | 8 | 4.2 | 0.0 | 0.0 |
| San Antonio | 693 | 242 | 301 | 29.28 | 29.99 | −.02 | 69.8 | −0.7 | 90 | 10 | 78 | 47 | 24 | 62 | 26 | 62 | 58 | 72 | 4.01 | +1.8 | 10 | 8,218 | e. | 35 | sw. | 6 | 9 | 7 | 15 | 6.2 | 0.0 | 0.0 |
| Taylor | 571 | 38 | 51 | 29.45 | 30.05 | +.03 | 67.2 | −1.1 | 88 | 10 | 77 | 40 | 25 | 58 | 30 | ---- | ---- | ---- | 6.55 | +3.5 | 10 | 4,553 | se. | 24 | se. | 4 | 12 | 11 | 8 | 4.4 | 0.0 | 0.0 |

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1930*—Continued

| District and station | Elevation of instruments: Barometer above sea level | Elevation of instruments: Thermometer above ground | Elevation of instruments: Anemometer above ground | Pressure: Station, reduced to mean of 24 hours | Pressure: Sea level, reduced to mean of 24 hours | Pressure: Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Temperature of the air: Departure from normal | Temperature of the air: Maximum | Temperature of the air: Date | Temperature of the air: Mean maximum | Temperature of the air: Minimum | Temperature of the air: Date | Temperature of the air: Mean minimum | Temperature of the air: Greatest daily range | Mean wet thermometer | Mean temperature of the dew-point | Mean relative humidity | Precipitation: Total | Precipitation: Departure from normal | Precipitation: Days with .01, or more | Wind: Total movement | Wind: Prevailing direction | Wind: Maximum velocity: Miles per hour | Wind: Maximum velocity: Direction | Wind: Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, and ice on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ohio Valley and Tennessee* | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | °F. | °F. | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % | *In.* | *In.* | | *Miles* | | | | | | | | *0–10* | *In.* | *In.* |
| | | | | | | | 55.2 | −2.5 | | | | | | | | | | 68 | 1.33 | −1.4 | | | | | | | | | | | 4.5 | | |
| Chattanooga | 762 | 190 | 215 | 29.30 | 30.12 | +0.03 | 58.7 | −3.2 | 81 | 16 | 68 | 33 | 31 | 30 | 29 | 51 | 45 | 67 | 2.81 | −0.2 | 5 | 4,128 | nw. | 28 | nw. | 30 | 16 | 6 | 9 | 4.3 | 0.0 | 0.0 |
| Knoxville | 995 | 102 | 111 | 29.07 | 30.13 | +.04 | 57.3 | −2.6 | 80 | 15 | 67 | 32 | 22 | 47 | 33 | 50 | 45 | 71 | 1.44 | −1.2 | 7 | 3,126 | sw. | 21 | sw. | 27 | 14 | 10 | 7 | 4.3 | T. | 0.0 |
| Memphis | 399 | 76 | 97 | 29.68 | 30.10 | +.03 | 61.5 | −1.8 | 84 | 11 | 70 | 32 | 31 | 53 | 27 | 53 | 47 | 65 | 1.96 | −0.7 | 6 | 4,228 | e. | 24 | w. | 30 | 15 | 7 | 9 | 4.5 | 0.0 | 0.0 |
| Nashville | 546 | 168 | 191 | 29.55 | 30.14 | +.06 | 58.6 | −2.4 | 84 | 11 | 69 | 32 | 31 | 49 | 34 | 51 | 46 | 71 | 2.11 | −0.4 | 6 | 4,804 | nw. | 30 | se. | 7 | 18 | 5 | 8 | 3.7 | T. | 0.0 |
| Lexington | 989 | 193 | 230 | 29.07 | 30.15 | +.07 | 54.7 | −2.7 | 82 | 11 | 64 | 27 | 20 | 46 | 31 | | | | 0.63 | −2.0 | 5 | 7,329 | e. | 36 | s. | 8 | 15 | 9 | 7 | 4.1 | T. | 0.0 |
| Louisville | 525 | 188 | 234 | 29.55 | 30.13 | +.05 | 56.4 | −2.9 | 85 | 11 | 65 | 31 | 20 | 47 | 32 | 48 | 42 | 65 | 0.80 | −1.8 | 6 | 5,433 | n. | 30 | nw. | 28 | 14 | 8 | 9 | 4.1 | T. | 0.0 |
| Evansville | 431 | 76 | 116 | 29.65 | 30.12 | +.04 | 57.2 | −2.2 | 86 | 11 | 66 | 30 | 20 | 48 | 30 | 50 | 44 | 69 | 1.31 | −1.5 | 9 | 4,815 | e. | 24 | sw. | 16 | 17 | 7 | 7 | 3.9 | T. | 0.0 |
| Indianapolis | 822 | 194 | 230 | 29.22 | 30.12 | +.05 | 53.6 | −2.1 | 83 | 12 | 62 | 25 | 20 | 45 | 28 | 46 | 39 | 65 | 1.77 | −1.0 | 7 | 6,447 | s. | 27 | nw. | 19 | 16 | 8 | 7 | 4.2 | T. | 0.0 |
| Royal Center | 736 | 11 | 55 | 29.31 | 30.12 | | 50.5 | | 82 | 12 | 60 | 20 | 20 | 41 | 31 | | | | 1.34 | −1.6 | 7 | 5,551 | e. | 27 | w. | 19 | 12 | 10 | 9 | 5.2 | 1.0 | 0.0 |
| Terre Haute | 575 | 96 | 129 | 29.49 | 30.11 | | 54.7 | | 84 | 12 | 64 | 26 | 20 | 45 | 30 | 47 | 42 | 68 | 1.73 | −1.0 | 5 | 5,020 | nw. | 24 | w. | 17 | 16 | 7 | 8 | 4.0 | 0.0 | 0.0 |
| Cincinnati | 627 | 11 | 51 | 29.44 | 30.13 | +.05 | 54.0 | −1.7 | 82 | 15 | 64 | 23 | 22 | 44 | 35 | 46 | 40 | 68 | 0.78 | −1.7 | 6 | 3,653 | ne. | 18 | sw. | 19 | 15 | 10 | 6 | 4.2 | 0.0 | 0.0 |
| Columbus | 822 | 216 | 230 | 29.24 | 30.12 | +.04 | 53.8 | −1.4 | 84 | 11 | 63 | 25 | 20 | 44 | 26 | 45 | 39 | 64 | 0.70 | −1.8 | 6 | 6,047 | ne. | 30 | w. | 19 | 11 | 6 | 4.5 | T. | T. |
| Dayton | 899 | 137 | 173 | 29.16 | 30.12 | | 53.6 | −1.4 | 82 | 12 | 63 | 26 | 22 | 44 | 30 | 46 | 41 | 70 | 1.17 | −1.4 | 6 | 4,451 | ne. | 27 | w. | 19 | 15 | 8 | 8 | 4.5 | T. | 0.0 |
| Elkins | 1,947 | 59 | 67 | 28.07 | 30.17 | +.07 | 47.5 | −4.8 | 79 | 11 | 61 | 14 | 22 | 34 | 47 | 40 | 35 | 76 | 0.82 | −2.1 | 6 | 2,693 | w. | 22 | w. | 17 | 7 | 17 | 7 | 5.5 | 0.4 | T. |
| Parkersburg | 637 | 77 | 82 | 29.48 | 30.15 | +.07 | 53.4 | −2.7 | 84 | 14 | 64 | 23 | 22 | 43 | 36 | 45 | 39 | 68 | 0.68 | −1.8 | 6 | 2,941 | se. | 19 | sw. | 30 | 13 | 5 | 13 | 5.5 | 0.0 | 0.0 |
| Pittsburgh | 842 | 353 | 410 | 29.22 | 30.13 | +.05 | 52.4 | −3.3 | 82 | 13 | 62 | 26 | 20 | 43 | 31 | 45 | 39 | 68 | 1.17 | −1.4 | 8 | 5,388 | w. | 30 | w. | 19 | 13 | 7 | 11 | 5.0 | T. | 0.0 |
| *Lower Lake Region* | | | | | | | 50.7 | −1.5 | | | | | | | | | | 74 | 1.84 | −1.0 | | | | | | | | | 5.9 | | |
| Buffalo | 767 | 247 | 280 | 29.24 | 30.08 | +.03 | 51.4 | −0.5 | 78 | 12 | 58 | 29 | 25 | 44 | 25 | 46 | 42 | 77 | 1.79 | −1.5 | 10 | 8,312 | w. | 44 | nw. | 19 | 8 | 9 | 14 | 6.0 | 1.9 | 0.0 |
| Canton | 448 | 10 | 61 | 29.59 | 30.07 | | 47.0 | −0.2 | 80 | 12 | 57 | 25 | 26 | 37 | 34 | | | | 1.83 | −1.2 | 9 | 4,195 | sw. | 25 | w. | 29 | 10 | 10 | 11 | 5.7 | 7.5 | 0.0 |
| Ithaca | 836 | 5 | 100 | 29.18 | 30.10 | | 49.1 | −2.0 | 84 | 14 | 60 | 26 | 23 | 38 | 39 | 43 | 39 | 77 | 1.41 | −1.6 | 8 | 4,767 | nw. | 25 | nw. | 25 | 8 | 11 | 12 | 6.0 | 1.2 | 0.0 |
| Oswego | 335 | 71 | 85 | 29.71 | 30.08 | +.03 | 49.1 | −2.1 | 75 | 13 | 56 | 31 | 19 | 42 | 28 | 45 | 41 | 76 | 2.25 | −1.0 | 11 | 5,296 | s. | 28 | n. | 25 | 7 | 10 | 14 | 6.3 | 3.2 | 0.0 |
| Rochester | 523 | 86 | 102 | 29.53 | 30.11 | +.06 | 50.4 | −1.1 | 80 | 13 | 59 | 30 | 20 | 42 | 29 | 44 | 40 | 74 | 1.83 | −0.8 | 10 | 4,130 | sw. | 25 | sw. | 19 | 7 | 8 | 16 | 6.3 | 2.5 | 0.0 |
| Syracuse | 596 | 65 | 79 | 29.43 | 30.08 | +.02 | 51.2 | +0.2 | 82 | 14 | 60 | 32 | 19 | 43 | 32 | | | | 1.30 | −1.5 | 12 | 3,513 | s. | 20 | nw. | 20 | 9 | 11 | 11 | 5.8 | 0.6 | 0.0 |
| Erie | 714 | 130 | 166 | 29.32 | 30.10 | +.05 | 51.6 | −1.8 | 80 | 13 | 59 | 28 | 19 | 44 | 23 | 46 | 41 | 72 | 3.23 | −0.5 | 13 | 8,156 | n. | 38 | sw. | 18 | 11 | 3 | 17 | 5.9 | 4.6 | 0.0 |
| Cleveland | 762 | 267 | 337 | 29.27 | 30.11 | +.05 | 51.8 | −1.8 | 77 | 13 | 58 | 30 | 20 | 46 | 27 | 45 | 39 | 64 | 1.52 | −1.3 | 9 | 8,837 | sw. | 38 | nw. | 31 | 9 | 6 | 16 | 6.2 | T. | 0.0 |
| Sandusky | 629 | 5 | 67 | 29.43 | 30.12 | +.06 | 51.3 | −3.0 | 79 | 16 | 60 | 26 | 20 | 43 | 31 | | | | 1.07 | −1.4 | 8 | 4,834 | e. | 22 | w. | 17 | 8 | 15 | 8 | 5.7 | T. | 0.0 |
| Toledo | 628 | 208 | 243 | 29.43 | 30.12 | +.07 | 51.0 | −2.4 | 77 | 13 | 59 | 27 | 20 | 44 | 27 | 45 | 40 | 71 | 1.82 | −0.6 | 8 | 6,984 | w. | 31 | w. | 19 | 13 | 7 | 11 | 5.1 | 0.5 | 0.0 |
| Fort Wayne | 856 | 100 | 119 | 29.18 | 30.12 | | 51.2 | −2.5 | 80 | 12 | 60 | 25 | 20 | 43 | 27 | 45 | 41 | 74 | 2.18 | −0.4 | 7 | 4,968 | e. | 26 | sw. | 19 | 9 | 11 | 11 | 5.5 | 0.2 | 0.0 |
| Detroit | 730 | 218 | 258 | 29.32 | 30.13 | +.08 | 51.6 | −0.9 | 80 | 13 | 58 | 28 | 20 | 45 | 24 | 46 | 43 | 80 | 1.80 | −0.6 | 8 | 5,417 | e. | 28 | w. | 18 | 8 | 11 | 12 | 5.8 | 1.4 | 0.0 |
| *Upper Lake Region* | | | | | | | 47.2 | −1.4 | | | | | | | | | | 80 | 1.96 | −0.8 | | | | | | | | | 6.7 | | |
| Alpena | 609 | 13 | 92 | 29.41 | 30.08 | +.05 | 44.3 | −2.8 | 71 | 13 | 51 | 25 | 20 | 37 | 24 | 41 | 39 | 86 | 1.11 | −1.6 | 15 | 5,798 | se. | 28 | nw. | 17 | 7 | 8 | 16 | 6.6 | 5.3 | 0.2 |
| Escanaba | 612 | 54 | 60 | 29.39 | 30.06 | +.05 | 45.4 | −0.6 | 64 | 11 | 51 | 21 | 22 | 40 | 25 | 42 | 38 | 79 | 1.09 | −1.5 | 5 | 6,224 | s. | 26 | nw. | 16 | 9 | 8 | 14 | 5.7 | T. | T. |
| Grand Haven | 632 | 54 | 89 | 29.39 | 30.08 | +.05 | 49.1 | −1.6 | 80 | 12 | 56 | 27 | 25 | 42 | 28 | 45 | 41 | 79 | 2.37 | −0.6 | 10 | 6,609 | se. | 37 | nw. | 19 | 6 | 5 | 20 | 7.2 | 1.0 | 0.0 |
| Grand Rapids | 707 | 70 | 244 | 29.33 | 30.11 | +.07 | 49.9 | −1.3 | 84 | 12 | 58 | 25 | 19 | 42 | 30 | 44 | 40 | 73 | 2.27 | −0.5 | 9 | 6,018 | se. | 33 | w. | 17 | 5 | 8 | 18 | 7.6 | 0.4 | 0.0 |
| Houghton | 668 | 64 | 99 | 29.29 | 30.03 | +.03 | 46.0 | +0.3 | 84 | 11 | 52 | 25 | 17 | 40 | 25 | | | | 3.30 | +0.3 | 14 | 6,727 | e. | 37 | w. | 18 | 5 | 5 | 21 | 7.7 | 9.1 | T. |
| Lansing | 878 | 6 | 49 | 29.14 | 30.10 | | 48.0 | −2.3 | 80 | 12 | 57 | 23 | 21 | 39 | 30 | 44 | 42 | 88 | 1.00 | −1.5 | 10 | 2,826 | w. | 14 | w. | 19 | 8 | 7 | 16 | 6.4 | 0.5 | 0.0 |
| Ludington | 637 | 60 | 66 | 29.38 | 30.08 | | 48.0 | −1.7 | 75 | 10 | 54 | 26 | 19 | 42 | 23 | 44 | 40 | 77 | 2.62 | −0.3 | 10 | 6,485 | w. | 30 | w. | 17 | 8 | 8 | 15 | 6.2 | 1.2 | T. |
| Marquette | 734 | 77 | 111 | 29.23 | 30.04 | +.03 | 46.8 | +0.1 | 82 | 11 | 53 | 25 | 17 | 40 | 23 | 42 | 39 | 81 | 1.75 | −1.0 | 12 | 7,151 | w. | 32 | sw. | 12 | 4 | 4 | 23 | 7.8 | 3.9 | 2.8 |
| Port Huron | 638 | 70 | 120 | 29.39 | 30.09 | +.05 | 49.0 | −1.5 | 79 | 13 | 56 | 26 | 22 | 42 | 29 | 44 | 42 | 80 | 0.98 | −1.5 | 8 | 5,836 | ne. | 26 | w. | 18 | 9 | 13 | 9 | 5.6 | 4.0 | 0.0 |
| Sault Sainte Marie | 614 | 11 | 52 | 29.37 | 30.07 | +.06 | 45.4 | +0.8 | 76 | 9 | 51 | 21 | 25 | 39 | 23 | 41 | 39 | 84 | 2.88 | −0.9 | 15 | 5,401 | se. | 30 | nw. | 17 | 6 | 8 | 17 | 6.7 | 11.7 | 0.0 |
| Chicago | 673 | 7 | 131 | 29.37 | 30.11 | +.07 | 51.6 | −2.4 | 80 | 10 | 58 | 24 | 20 | 45 | 27 | 46 | 41 | 72 | 2.81 | +0.3 | 7 | 6,186 | nw. | 25 | w. | 17 | 10 | 12 | 9 | 5.4 | T. | 0.0 |
| Green Bay | 617 | 109 | 141 | 29.39 | 30.06 | +.04 | 47.6 | −0.9 | 81 | 12 | 54 | 22 | 19 | 41 | 29 | 42 | 38 | 76 | 1.70 | −0.8 | 6 | 6,851 | s. | 30 | w. | 19 | 7 | 3 | 21 | 7.2 | T. | 0.0 |
| Milwaukee | 681 | 125 | 221 | 29.34 | 30.09 | +.06 | 48.1 | −3.0 | 78 | 13 | 55 | 24 | 19 | 42 | 30 | 44 | 40 | 79 | 2.01 | −0.3 | 7 | 7,627 | w. | 33 | se. | 7 | 10 | 8 | 13 | 6.0 | T. | 0.0 |
| Duluth | 1,133 | 5 | 47 | 28.80 | 30.04 | +.04 | 41.8 | −2.3 | 78 | 12 | 49 | 16 | 31 | 34 | 32 | 38 | 36 | 84 | 1.53 | −0.8 | 12 | 7,484 | ne. | 42 | nw. | 16 | 5 | 6 | 20 | 7.2 | 0.4 | 0.0 |
| *North Dakota* | | | | | | | 41.0 | −2.8 | | | | | | | | | | 77 | 1.61 | +0.4 | | | | | | | | | 6.4 | | |
| Moorhead | 940 | 50 | 58 | 28.98 | 30.01 | +.01 | 43.6 | −0.9 | 84 | 11 | 52 | 12 | 21 | 35 | 32 | 39 | 35 | 77 | 1.37 | −0.3 | 12 | 6,206 | s. | 26 | nw. | 17 | 4 | 8 | 19 | 7.6 | 0.2 | T. |
| Bismarck | 1,674 | 8 | 57 | 28.21 | 30.02 | +.03 | 41.4 | −3.5 | 73 | 8 | 50 | 14 | 18 | 32 | 36 | 37 | 32 | 73 | 1.94 | +1.0 | 11 | 6,404 | nw. | 42 | nw. | 17 | 13 | 6 | 12 | 5.2 | T. | 0.0 |
| Devils Lake | 1,478 | 11 | 44 | 28.41 | 30.01 | +.02 | 39.7 | −2.7 | 67 | 11 | 48 | 14 | 18 | 32 | 29 | 36 | 33 | 84 | 2.26 | +1.0 | 11 | 6,759 | nw. | 37 | nw. | 17 | 3 | 12 | 16 | 7.3 | T. | 0.0 |
| Ellendale | 1,457 | 10 | 56 | 28.43 | 30.01 | | 42.8 | | 77 | 11 | 52 | 9 | 21 | 33 | 38 | | | | 1.80 | +0.6 | 11 | 8,985 | nw. | 46 | nw. | 17 | 7 | 6 | 18 | 6.9 | 0.1 | 0.0 |
| Grand Forks | 833 | 12 | 67 | | | | 41.6 | | 79 | 11 | 50 | 12 | 31 | 33 | 32 | 38 | | | 1.88 | | 11 | | nw. | 35 | w. | 17 | 3 | 11 | 17 | | 0.4 | 0.0 |
| Williston | 1,878 | 41 | 48 | 28.03 | 30.05 | +.07 | 39.4 | −4.0 | 70 | 8 | 50 | 11 | 18 | 29 | 38 | 34 | 30 | 74 | 0.66 | −0.2 | 7 | 5,367 | nw. | 37 | w. | 16 | 12 | 10 | 9 | 4.9 | T. | 0.0 |
| *Upper Mississippi Valley* | | | | | | | 51.9 | −1.2 | | | | | | | | | | 74 | 2.03 | −0.4 | | | | | | | | | 5.3 | | |
| Minneapolis | 918 | 102 | 208 | 29.03 | 30.02 | | 47.8 | −1.1 | 86 | 10 | 56 | 21 | 19 | 40 | 30 | | | | 1.14 | −0.9 | 10 | 8,360 | s. | 30 | w. | 17 | 7 | 9 | 15 | 6.7 | 0.5 | T. |
| St. Paul | 837 | 236 | 261 | 29.11 | 30.03 | +.02 | 47.2 | −1.4 | 84 | 10 | 55 | 20 | 19 | 40 | 27 | | | | 1.50 | −0.7 | 9 | 8,797 | se. | 37 | w. | 17 | 5 | 9 | 17 | 6.8 | 0.9 | 0.0 |
| La Crosse | 714 | 11 | 48 | 29.27 | 30.05 | +.03 | 48.8 | −1.5 | 85 | 10 | 57 | 19 | 22 | 40 | 30 | 43 | 40 | 77 | 1.66 | −0.7 | 9 | 3,189 | s. | 16 | sw. | 17 | 8 | 6 | 17 | 6.4 | T. | 0.0 |
| Madison | 974 | 70 | 78 | 29.02 | 30.06 | +.05 | 48.1 | −2.2 | 82 | 10 | 55 | 21 | 19 | 41 | 27 | 43 | 40 | 77 | 1.63 | −0.8 | 7 | 5,232 | s. | 24 | w. | 17 | 8 | 12 | 11 | 5.8 | T. | 0.0 |
| Wausau | 1,247 | 4 | 62 | | 30.08 | | 46.2 | | 82 | 10 | 53 | 19 | 22 | 39 | 29 | | | | 2.89 | +0.1 | 6 | 4,495 | se. | 24 | w. | 18 | 8 | 4 | 19 | | T. | 0.0 |
| Charles City | 1,015 | 10 | 51 | 28.99 | 30.08 | +.06 | 48.0 | −0.6 | 86 | 10 | 56 | 18 | 20 | 40 | 28 | 42 | 39 | 77 | 1.78 | −0.6 | 12 | 4,508 | se. | 23 | w. | 17 | 10 | 7 | 14 | 5.9 | 2.0 | T. |
| Davenport | 606 | 71 | 79 | 29.42 | 30.09 | +.05 | 52.2 | −1.5 | 88 | 10 | 61 | 23 | 21 | 44 | 28 | 46 | 42 | 74 | 2.89 | +0.5 | 9 | 5,671 | se. | 34 | w. | 17 | 12 | 7 | 12 | 5.2 | T. | 0.0 |
| Des Moines | 861 | 5 | 99 | 29.16 | 30.08 | +.05 | 52.3 | −1.1 | 86 | 10 | 61 | 21 | 21 | 44 | 32 | 46 | 41 | 71 | 2.64 | +0.1 | 10 | 6,239 | se. | 34 | w. | 17 | 12 | 5 | 14 | 5.5 | 0.5 | T. |
| Dubuque | 700 | 81 | 96 | 29.32 | 30.08 | +.04 | 50.1 | −1.8 | 86 | 10 | 58 | 22 | 20 | 42 | 27 | 45 | 41 | 75 | 2.59 | +0.1 | 9 | 3,648 | s. | 18 | nw. | 16 | 8 | 10 | 13 | 6.0 | T. | 0.0 |
| Keokuk | 614 | 64 | 78 | 29.42 | 30.11 | +.06 | 54.0 | −1.4 | 84 | 10 | 63 | 24 | 21 | 45 | 27 | 47 | 42 | 71 | 2.00 | −0.3 | 5 | 4,349 | nw. | 28 | w. | 17 | 15 | 7 | 9 | 4.6 | T. | 0.0 |
| Cairo | 358 | 87 | 93 | 29.72 | 30.11 | +.04 | 58.6 | −1.8 | 84 | 12 | 67 | 32 | 31 | 50 | 28 | 51 | 46 | 72 | 1.05 | −1.7 | 7 | 4,334 | n. | 22 | nw. | 30 | 14 | 8 | 9 | 4.5 | T. | 0.0 |
| Peoria | 609 | 11 | 45 | 29.44 | 30.12 | +.07 | 53.0 | +1.0 | 86 | 10 | 62 | 22 | 21 | 43 | 33 | 46 | 42 | 74 | 3.14 | +0.8 | 6 | 3,498 | se. | 18 | sw. | 17 | 18 | 5 | 8 | 4.0 | T. | 0.0 |
| Springfield, Ill. | 636 | 5 | 191 | 29.41 | 30.10 | +.05 | 53.9 | −1.9 | 85 | 10 | 63 | 25 | 21 | 45 | 32 | 48 | 44 | 78 | 1.44 | −1.1 | 7 | 7,527 | se. | 34 | s. | 7 | 14 | 9 | 8 | 4.5 | 0.3 | 0.0 |
| Hannibal | 534 | 74 | 109 | 29.52 | 30.10 | +.05 | 55.4 | −0.6 | 88 | 9 | 65 | 24 | 20 | 46 | 31 | | | | 2.22 | −0.2 | 4 | 4,820 | nw. | 25 | w. | 17 | 17 | 6 | 8 | 4.1 | T. | 0.0 |
| St. Louis | 568 | 265 | 303 | 29.49 | 30.10 | +.04 | 57.1 | −1.2 | 84 | 10 | 65 | 31 | 31 | 49 | 30 | 49 | 44 | 67 | 1.84 | −0.9 | 6 | 7,144 | s. | 31 | s. | 7 | 18 | 4 | 9 | 3.6 | T. | 0.0 |
| *Missouri Valley* | | | | | | | 52.5 | −1.2 | | | | | | | | | | 69 | 2.56 | +0.5 | | | | | | | | | 4.9 | | |
| Columbia, Mo. | 784 | 6 | 84 | 29.25 | 30.09 | +.04 | 55.2 | −1.4 | 85 | 9 | 64 | 22 | 31 | 46 | 29 | | | | 2.57 | 0.0 | 6 | 4,358 | se. | 23 | nw. | 30 | 14 | 9 | 8 | 4.3 | T. | 0.0 |
| Kansas City | 963 | 161 | 181 | 29.05 | 30.10 | +.06 | 58.4 | −1.3 | 88 | 9 | 65 | 28 | 31 | 48 | 28 | 48 | 43 | 68 | 2.10 | −0.8 | 11 | 5,691 | s. | 28 | nw. | 16 | 14 | 8 | 9 | 4.6 | T. | 0.0 |
| St. Joseph | 967 | 11 | 49 | 29.03 | 30.08 | | 55.0 | | 86 | 9 | 64 | 23 | 31 | 46 | 32 | 47 | 42 | 70 | 3.99 | +1.3 | 10 | 5,087 | se. | 29 | nw. | 29 | 14 | 9 | 8 | 4.3 | T. | 0.0 |
| Springfield, Mo. | 1,324 | 98 | 104 | 28.70 | 30.12 | +.07 | 55.5 | −2.7 | 84 | 9 | 64 | 26 | 31 | 47 | 30 | 48 | 43 | 72 | 3.05 | 0.0 | 7 | 6,190 | se. | 28 | se. | 6 | 20 | 5 | 6 | 3.2 | 0.0 | 0.0 |
| Iola | 964 | 11 | 50 | 29.03 | 30.08 | +.04 | 55.8 | −2.0 | 85 | 9 | 66 | 22 | 31 | 46 | 32 | | | | 3.43 | +0.4 | 9 | 3,401 | se. | 17 | n. | 16 | 14 | 5 | 12 | 5.2 | 0.0 | 0.0 |
| Topeka | 987 | 92 | 107 | | | | 55.5 | −1.5 | 87 | 9 | 64 | 25 | 31 | 47 | 30 | | | | 5.07 | +2.6 | 11 | 5,837 | s. | 30 | n. | 16 | 12 | 7 | 12 | 5.1 | 0.3 | 0.0 |
| Lincoln | 1,189 | 11 | 81 | 28.79 | 30.06 | +.03 | 53.6 | −0.6 | 88 | 10 | 64 | 17 | 31 | 44 | 40 | 46 | 40 | 66 | 0.52 | −1.4 | 5 | 6,539 | s. | 34 | w. | 17 | 12 | 8 | 11 | 5.1 | T. | 0.0 |
| Omaha | 1,105 | 115 | 122 | 28.88 | 30.07 | +.04 | 53.6 | −0.7 | 88 | 10 | 62 | 22 | 31 | 45 | 32 | 46 | 39 | 65 | 0.81 | −1.4 | 8 | 4,978 | s. | 30 | nw. | 16 | 13 | 10 | 8 | 4.4 | T. | 0.0 |
| Valentine | 2,598 | 47 | 54 | 27.31 | 30.06 | +.05 | 47.8 | −1.5 | 88 | 10 | 59 | 18 | 19 | 36 | 44 | 40 | 34 | 70 | 2.88 | +1.8 | 8 | 5,825 | w. | 30 | nw. | 17 | 11 | 10 | 10 | 5.2 | 0.5 | 0.0 |
| Sioux City | 1,135 | 94 | 164 | 28.84 | 30.06 | +.04 | 51.2 | +0.3 | 88 | 10 | 60 | 17 | 31 | 42 | 35 | 44 | 39 | 68 | 1.60 | −0.2 | 7 | 8,585 | nw. | 42 | nw. | 17 | 11 | 10 | 10 | 5.2 | 0.2 | 0.0 |
| Huron | 1,306 | 59 | 74 | 28.63 | 30.05 | +.04 | 46.9 | −0.8 | 85 | 10 | 57 | 13 | 21 | 37 | 38 | 41 | 36 | 72 | 3.61 | +2.3 | 8 | 6,247 | se. | 34 | w. | 17 | 10 | 10 | 11 | 5.3 | T. | 0.0 |
| Pierre | 1,572 | 70 | 75 | 28.34 | 30.03 | +.02 | 48.0 | −1.8 | 83 | 8 | 58 | 17 | 19 | 38 | 37 | 41 | 35 | 70 | 2.34 | +1.5 | 11 | 6,068 | nw. | 37 | nw. | 17 | 11 | 11 | 9 | 5.1 | T. | 0.0 |
| Yankton | 1,233 | 49 | 57 | 28.71 | 30.04 | +.03 | 50.2 | −0.9 | 88 | 10 | 60 | 16 | 31 | 40 | 34 | | | | 1.29 | −0.1 | 7 | 5,323 | nw. | 29 | uw | 17 | 7 | 12 | 12 | 5.9 | T. | 0.0 |

TABLE 1.—*Climatological data for Weather Bureau stations, October, 1930*—Continued

| District and station | Elevation of instruments: Barometer above sea level | Elevation of instruments: Thermometer above ground | Elevation of instruments: Anemometer above ground | Pressure: Station, reduced to mean of 24 hours | Pressure: Sea level, reduced to mean of 24 hours | Pressure: Departure from normal | Temperature of the air: Mean max. + mean min. ÷ 2 | Temperature of the air: Departure from normal | Temperature of the air: Maximum | Temperature of the air: Date | Temperature of the air: Mean maximum | Temperature of the air: Minimum | Temperature of the air: Date | Temperature of the air: Mean minimum | Temperature of the air: Greatest daily range | Mean wet thermometer | Mean temperature of the dew-point | Mean relative humidity | Precipitation: Total | Precipitation: Departure from normal | Precipitation: Days with .01, or more | Wind: Total movement | Wind: Prevailing direction | Wind: Maximum velocity: Miles per hour | Wind: Maximum velocity: Direction | Wind: Maximum velocity: Date | Clear days | Partly cloudy days | Cloudy days | Average cloudiness, tenths | Total snowfall | Snow, sleet, andince on ground at end of month |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Ft.* | *Ft.* | *Ft.* | *In.* | *In.* | *In.* | °F. | °F. | °F. | | °F. | °F. | | °F. | °F. | °F. | °F. | % | *In.* | *In.* | | *Miles* | | | | | | | | *0–10* | *In.* | *In.* |
| *Northern Slope* | | | | | | | 43.1 | −2.2 | | | | | | | | | | 71 | 1.99 | +1.0 | | | | | | | | | | 5.8 | | |
| Billings | 3,140 | 5 | | | | | 41.1 | | 72 | 8 | 52 | 14 | 17 | 30 | 46 | | | | 1.82 | | 14 | | nw. | | | 5 | 9 | 17 | | 1.0 | 0.0 |
| Havre | 2,505 | 11 | 44 | 27.41 | 30.09 | +0.11 | 39.7 | −4.8 | 72 | 4 | 51 | 9 | 17 | 29 | 41 | 33 | 28 | 73 | 0.48 | −0.2 | 7 | 5,657 | nw. | 31 | sw. | 26 | 10 | 9 | 12 | 5.6 | 0.5 | 0.0 |
| Helena | 4,124 | 89 | 113 | 25.83 | 30.07 | +.04 | 41.9 | −3.0 | 68 | 4 | 50 | 11 | 17 | 34 | 27 | 36 | 30 | 66 | 1.20 | +0.3 | 11 | 4,217 | sw. | 23 | sw. | 27 | 5 | 5 | 21 | 7.4 | 3.7 | 0.0 |
| Kalispell | 2,973 | 48 | 56 | 26.99 | 30.08 | +.07 | 41.4 | −2.1 | 72 | 2 | 50 | 18 | 16 | 33 | 29 | 37 | 33 | 75 | 1.61 | +0.6 | 11 | 2,387 | nw. | 16 | ne. | 15 | 6 | 9 | 16 | 6.8 | 2.5 | 0.0 |
| Miles City | 2,371 | 48 | 55 | 27.52 | 30.12 | +.12 | 42.0 | −4.5 | 72 | 8 | 53 | 13 | 19 | 32 | 39 | 36 | 31 | 71 | 0.66 | −0.2 | 11 | 3,643 | s. | 25 | w. | 16 | 11 | 6 | 14 | 5.7 | 0.2 | 0.0 |
| Rapid City | 3,259 | 50 | 58 | 26.64 | 30.09 | +.08 | 45.4 | −3.1 | 80 | 8 | 55 | 18 | 16 | 36 | 43 | 39 | 32 | 67 | 3.58 | +2.6 | 8 | 4,703 | n. | 30 | nw. | 2 | 10 | 11 | 10 | 5.7 | 0.6 | 0.0 |
| Cheyenne | 6,088 | 84 | 101 | 24.02 | 30.02 | +.01 | 44.4 | −0.4 | 72 | 9 | 56 | 19 | 17 | 32 | 38 | 36 | 30 | 65 | 1.49 | +0.5 | 10 | 6,990 | w. | 42 | w. | 15 | 12 | 10 | 9 | 4.7 | T. | 0.0 |
| Lander | 5,372 | 60 | 68 | 24.65 | 30.05 | +.01 | 43.8 | +0.3 | 69 | 8 | 57 | 14 | 17 | 31 | 38 | 36 | 31 | 70 | 2.36 | +1.0 | 6 | 2,754 | sw. | 33 | sw. | 25 | 17 | 9 | 5 | 3.8 | 1.5 | 0.0 |
| Sheridan | 3,790 | 10 | 47 | 26.13 | 30.08 | | 41.4 | | 76 | 8 | 52 | 12 | 7 | 31 | 48 | 36 | 32 | 76 | 2.02 | +1.0 | 15 | 2,273 | nw. | 28 | nw. | 27 | 8 | 6 | 17 | 6.6 | 3.5 | 0.0 |
| Yellowstone Park | 6,241 | 11 | 48 | 23.90 | 30.09 | +.07 | 38.3 | −3.2 | 56 | 19 | 48 | 11 | 17 | 29 | 33 | 33 | 28 | 72 | 2.39 | +1.0 | 15 | 4,007 | sw. | 28 | sw. | 14 | 4 | 10 | 17 | 7.0 | 9.5 | 0.0 |
| North Platte | 2,821 | 11 | 51 | 27.09 | 30.04 | +.02 | 50.6 | +0.9 | 86 | 10 | 62 | 23 | 30 | 39 | 44 | 43 | 38 | 72 | 4.15 | +3.1 | 8 | 4,177 | se. | 22 | n. | 27 | 15 | 5 | 11 | 4.8 | 0.5 | 0.0 |
| *Middle Slope* | | | | | | | 54.5 | −1.4 | | | | | | | | | | 67 | 2.72 | +0.8 | | | | | | | | | | 4.7 | | |
| Denver | 5,292 | 106 | 113 | 24.73 | 29.99 | −.02 | 50.2 | −1.0 | 80 | 9 | 61 | 26 | 17 | 39 | 38 | 40 | 30 | 52 | 0.63 | −0.4 | 7 | 4,406 | s. | 32 | ne. | 15 | 16 | 11 | 4 | 3.8 | 0.5 | 0.0 |
| Pueblo | 4,685 | 80 | 86 | 25.27 | 29.95 | −.04 | 51.3 | −0.7 | 82 | 9 | 65 | 21 | 31 | 38 | 51 | 41 | 32 | 58 | 0.57 | −0.1 | 9 | 3,726 | nw. | 23 | s. | 10 | 16 | 10 | 5 | 3.8 | 0.0 | 0.0 |
| Concordia | 1,392 | 50 | 58 | 28.61 | 30.10 | +.07 | 53.8 | −2.1 | 87 | 9 | 63 | 23 | 31 | 45 | 34 | 47 | 42 | 71 | 2.32 | +0.4 | 8 | 4,745 | s. | 28 | nw. | 15 | 11 | 7 | 13 | 5.4 | T. | 0.0 |
| Dodge City | 2,509 | 11 | 51 | 27.46 | 30.07 | +.03 | 54.8 | −1.3 | 90 | 9 | 65 | 29 | 21 | 45 | 38 | 48 | 44 | 78 | 4.24 | +2.9 | 9 | 5,699 | se. | 28 | se. | 11 | 13 | 6 | 12 | 4.9 | 0.0 | 0.0 |
| Wichita | 1,358 | 139 | 158 | 28.62 | 30.06 | +.03 | 56.6 | −2.0 | 86 | 9 | 64 | 29 | 31 | 49 | 26 | 50 | 45 | 71 | 2.55 | 0.0 | 7 | 7,606 | s. | 36 | sw. | 15 | 14 | 7 | 10 | 4.8 | 0.0 | 0.0 |
| Broken Arrow | 765 | 11 | 56 | 29.24 | 30.07 | | 59.3 | | 86 | 9 | 69 | 29 | 31 | 50 | 31 | | | | 2.62 | −0.7 | 6 | 7,733 | se. | 34 | n. | 28 | 14 | 5 | 12 | 4.8 | 0.0 | 0.0 |
| Oklahoma City | 1,214 | 10 | 47 | 28.78 | 30.06 | +.03 | 60.5 | −1.0 | 87 | 9 | 69 | 35 | 31 | 52 | 30 | 53 | 48 | 73 | 6.10 | +3.2 | 10 | 5,771 | s. | 22 | s. | 15 | 11 | 10 | 10 | 5.3 | 0.0 | 0.0 |
| *Southern Slope* | | | | | | | 62.6 | −0.6 | | | | | | | | | | 75 | 5.82 | +4.0 | | | | | | | | | | 5.5 | | |
| Abilene | 1,738 | 10 | 52 | 28.22 | 30.03 | +.02 | 63.9 | −1.5 | 87 | 8 | 72 | 39 | 29 | 56 | 27 | 57 | 54 | 77 | 6.25 | +3.8 | 12 | 6,038 | s. | 28 | sw. | 26 | 12 | 6 | 13 | 5.5 | 0.0 | 0.0 |
| Amarillo | 3,676 | 10 | 49 | 26.30 | 30.02 | +.02 | 56.8 | −0.9 | 88 | 9 | 66 | 34 | 31 | 47 | 34 | 49 | 45 | 75 | 2.57 | +0.9 | 11 | 6,205 | s. | 31 | se. | 1 | 14 | 4 | 13 | 4.9 | 0.0 | 0.0 |
| Del Rio | 944 | 64 | 71 | 28.98 | 29.96 | −.02 | 69.1 | −0.9 | 90 | 8 | 76 | 45 | 30 | 62 | 25 | 63 | 59 | 76 | 11.69 | +9.9 | 15 | 5,791 | se. | 21 | nw. | 23 | 6 | 7 | 18 | 6.5 | 0.0 | 0.0 |
| Roswell | 3,566 | 75 | 85 | 26.37 | 29.96 | .00 | 60.4 | +0.9 | 85 | 9 | 70 | 35 | 30 | 50 | 36 | 53 | 49 | 73 | 2.76 | +1.3 | 13 | 4,677 | s. | 32 | nw. | 1 | 12 | 8 | 11 | 5.0 | 0.0 | 0.0 |
| *Southern Plateau* | | | | | | | 60.1 | +0.1 | | | | | | | | | | 48 | 0.36 | −0.2 | | | | | | | | | | 1.6 | | |
| El Paso | 3,778 | 152 | 175 | 26.16 | 29.89 | −.03 | 65.8 | +2.3 | 90 | 1 | 77 | 41 | 29 | 54 | 32 | 54 | 45 | 55 | 0.75 | 0.0 | 6 | 6,117 | e. | 48 | ne. | 5 | 26 | 2 | 3 | 2.2 | 0.0 | 0.0 |
| Santa Fe | 7,013 | 38 | 53 | 23.26 | 29.93 | −.03 | 50.5 | +0.1 | 72 | 9 | 62 | 27 | 29 | 38 | 32 | 39 | 30 | 52 | 0.64 | −0.5 | 6 | 3,997 | se. | 18 | nw. | 14 | 19 | 9 | 3 | 2.8 | 0.0 | 0.0 |
| Flagstaff | 6,907 | 10 | 59 | 23.35 | 29.92 | .00 | 44.9 | +0.2 | 68 | 16 | 61 | 20 | 24 | 29 | 42 | 35 | | 60 | 0.13 | | 1 | 5,366 | w. | 30 | s. | 9 | 23 | 6 | 2 | | T. | 0.0 |
| Phoenix | 1,108 | 10 | 107 | 28.68 | 29.83 | −.05 | 70.4 | −0.2 | 95 | 17 | 87 | 47 | 11 | 54 | 43 | 52 | 36 | 35 | 0.16 | −0.3 | 1 | 3,070 | e. | 18 | sw. | 9 | 27 | 3 | 1 | 1.2 | 0.0 | 0.0 |
| Yuma | 141 | 9 | 54 | 29.68 | 29.83 | −.04 | 72.0 | −1.3 | 98 | 7 | 88 | 48 | 11 | 56 | 40 | 55 | 40 | 38 | 0.20 | −0.1 | 2 | 3,271 | n. | 26 | n. | 26 | 31 | 0 | 0 | 0.3 | 0.0 | 0.0 |
| Independence | 3,957 | 6 | 27 | 25.96 | 29.99 | +.04 | 57.0 | −0.5 | 85 | 6 | 74 | 29 | 30 | 41 | 45 | 42 | | | 0.07 | −0.3 | 1 | | nw. | | | | 24 | 5 | 2 | | 0.0 | 0.0 |
| *Middle Plateau* | | | | | | | 49.1 | −1.2 | | | | | | | | | | 50 | 0.69 | −0.1 | | | | | | | | | | 2.7 | | |
| Reno | 4,832 | 74 | 81 | 25.49 | 30.01 | +.02 | 50.8 | +1.1 | 76 | 23 | 66 | 24 | 26 | 35 | 44 | 40 | 29 | 50 | 0.07 | −0.3 | 1 | 3,538 | w. | 36 | sw. | 7 | 23 | 6 | 2 | 2.1 | 0.0 | 0.0 |
| Tonopah | 6,090 | 12 | 20 | | | | 50.8 | | 73 | 7 | 61 | 28 | 26 | 40 | 24 | 39 | 28 | 44 | 0.06 | | 2 | | nw. | | | | | | | | | |
| Winnemucca | 4,344 | 18 | 56 | 25.65 | 30.07 | +.02 | 46.0 | −2.3 | 75 | 7 | 64 | 15 | 26 | 28 | 53 | 36 | 26 | 53 | 0.26 | −0.4 | 4 | 3,724 | ne. | 26 | sw. | 7 | 18 | 10 | 3 | 3.1 | 0.0 | 0.0 |
| Modena | 5,473 | 10 | 43 | 24.62 | 29.97 | +.01 | 46.0 | −2.0 | 72 | 7 | 62 | 19 | 29 | 30 | 47 | 36 | 26 | 54 | 1.09 | +0.4 | 4 | 6,207 | w. | 40 | s. | 8 | 23 | 6 | 2 | 2.2 | 0.7 | 0.0 |
| Salt Lake City | 4,360 | 163 | 203 | 25.65 | 30.03 | +.02 | 49.8 | −2.7 | 71 | 8 | 59 | 30 | 16 | 41 | 28 | 42 | 34 | 58 | 1.42 | 0.0 | 9 | 4,174 | nw. | 26 | nw. | 8 | 17 | 9 | 5 | 3.8 | T. | 0.0 |
| Grand Junction | 4,602 | 60 | 68 | 25.38 | 29.96 | −.03 | 52.9 | +0.1 | 79 | 9 | 66 | 30 | 29 | 39 | 37 | 40 | 27 | 44 | 0.62 | −0.3 | 4 | 3,603 | n. | 26 | s. | 10 | 21 | 9 | 1 | 2.4 | 0.0 | 0.0 |
| *Northern Plateau* | | | | | | | 48.1 | −1.8 | | | | | | | | | | 66 | 0.98 | −0.2 | | | | | | | | | | 5.3 | | |
| Baker | 3,471 | 48 | 53 | 26.50 | 30.11 | +.03 | 43.9 | −2.7 | 69 | 5 | 57 | 18 | 28 | 31 | 37 | 38 | 31 | 63 | 0.29 | −0.6 | 3 | 3,272 | se. | 17 | se. | 23 | 13 | 10 | 8 | 4.5 | T. | 0.0 |
| Boise | 2,739 | 78 | 86 | 27.21 | 30.08 | +.02 | 49.6 | −1.5 | 72 | 4 | 61 | 29 | 16 | 38 | 37 | 43 | 36 | 63 | 0.87 | −0.4 | 6 | 2,514 | se. | 21 | nw. | 14 | 11 | 13 | 7 | 4.6 | 0.0 | 0.0 |
| Lewiston | 757 | 40 | 48 | 29.27 | 30.09 | +.02 | 50.6 | −0.9 | 78 | 3 | 61 | 27 | 30 | 40 | 35 | | | | 1.08 | −0.2 | 6 | 1,404 | e. | 23 | sw. | 14 | 9 | 7 | 15 | 6.0 | 0.0 | 0.0 |
| Pocatello | 4,477 | 60 | 68 | 25.50 | 30.04 | .00 | 47.6 | −0.8 | 70 | 19 | 59 | 25 | 28 | 37 | 35 | 40 | 33 | 64 | 1.65 | +0.5 | 10 | 4,609 | se. | 24 | sw. | 25 | 10 | 9 | 12 | 5.5 | T. | 0.0 |
| Spokane | 1,929 | 101 | 110 | 28.02 | 30.09 | +.03 | 46.2 | −2.1 | 75 | 3 | 56 | 26 | 13 | 37 | 35 | 42 | 37 | 71 | 1.02 | −0.2 | 6 | 3,027 | s. | 22 | sw. | 26 | 8 | 9 | 14 | 5.9 | 0.6 | 0.0 |
| Walla Walla | 991 | 57 | 65 | 29.01 | 30.09 | +.02 | 50.6 | −2.9 | 75 | 3 | 59 | 33 | 30 | 42 | 31 | 45 | 40 | 67 | 1.00 | −0.5 | 9 | 2,039 | s. | 22 | w. | 14 | 12 | 7 | 12 | 5.5 | 0.0 | 0.0 |
| *North Pacific Coast Region* | | | | | | | 51.5 | −0.3 | | | | | | | | | | 75 | 3.22 | 0.0 | | | | | | | | | | 6.1 | | |
| North Head | 211 | 11 | 56 | 29.84 | 30.07 | +.02 | 53.2 | +0.3 | 67 | 29 | 57 | 43 | 28 | 49 | 21 | 50 | 47 | 83 | 3.26 | −1.8 | 16 | 8,299 | n. | 42 | s. | 26 | 4 | 12 | 15 | 7.2 | 0.0 | 0.0 |
| Port Angeles | 29 | 8 | 53 | | 30.08 | | 47.1 | | 62 | 4 | 54 | 33 | 13 | 41 | 21 | | | | 2.99 | +0.6 | 14 | 3,259 | s. | 30 | w. | 26 | 4 | 12 | 15 | | 0.0 | 0.0 |
| Seattle | 125 | 215 | 250 | 29.93 | 30.06 | +.01 | 51.0 | −0.4 | 66 | 1 | 57 | 38 | 29 | 45 | 22 | 48 | 45 | 80 | 2.72 | −0.1 | 14 | 4,116 | se. | 28 | s. | 26 | 3 | 16 | 12 | 6.8 | 0.0 | 0.0 |
| Tacoma | 194 | 172 | 201 | 29.86 | 30.07 | +.03 | 50.3 | −0.2 | 66 | 1 | 58 | 34 | 11 | 43 | 25 | | | | 2.01 | −1.3 | 11 | 4,111 | s. | 30 | s. | 26 | 5 | 10 | 16 | 7.1 | 0.0 | 0.0 |
| Tatoosh Island | 86 | 9 | 53 | 29.93 | 30.03 | +.02 | 50.2 | +0.3 | 59 | 30 | 54 | 37 | 16 | 47 | 14 | 48 | 47 | 90 | 14.54 | +6.4 | 17 | 9,931 | e. | 44 | e. | 29 | 7 | 7 | 17 | 6.7 | 0.0 | 0.0 |
| Yakima | 1,076 | 58 | 67 | 28.92 | 30.08 | | 48.9 | −1.3 | 80 | 3 | 62 | 24 | 15 | 36 | 37 | 42 | 34 | 61 | 0.24 | −0.4 | 4 | 2,445 | nw. | 26 | sw. | 14 | 15 | 8 | 8 | 4.4 | 0.0 | 0.0 |
| Medford | 1,329 | 29 | 58 | 28.64 | 30.05 | | 53.5 | | 83 | 3 | 69 | 27 | 15 | 38 | 44 | 46 | 39 | 65 | 0.30 | −1.0 | 5 | | s. | 21 | n. | | 14 | 11 | 14 | 6 | 4.5 | 0.0 | 0.0 |
| Portland, Oreg | 153 | 68 | 106 | 29.91 | 30.07 | +.01 | 53.7 | −0.5 | 69 | 1 | 61 | 38 | 16 | 46 | 24 | 49 | 44 | 74 | 2.15 | −1.0 | 12 | 3,068 | nw. | 18 | e. | 20 | 5 | 13 | 13 | 6.5 | 0.0 | 0.0 |
| Roseburg | 510 | 75 | 99 | 29.52 | 30.08 | .00 | 53.4 | −0.5 | 75 | 22 | 65 | 35 | 15 | 42 | 36 | 49 | 44 | 73 | 0.80 | −1.8 | 7 | 1,610 | nw. | 20 | sw. | 7 | 9 | 13 | 9 | 5.4 | 0.0 | 0.0 |
| *Middle Pacific Coast Region* | | | | | | | 60.8 | +0.5 | | | | | | | | | | 66 | 0.65 | −0.6 | | | | | | | | | | 2.7 | | |
| Eureka | 62 | 73 | 89 | 30.00 | 30.07 | +.01 | 52.6 | −1.0 | 67 | 28 | 59 | 39 | 15 | 46 | 24 | 51 | 49 | 87 | 1.21 | −1.1 | 6 | 2,485 | n. | 22 | nw. | 14 | 12 | 9 | 10 | 4.8 | 0.0 | 0.0 |
| Red Bluff | 330 | 5 | 58 | 29.60 | 29.96 | −.07 | 64.2 | −0.1 | 93 | 4 | 79 | 43 | 25 | 50 | 38 | 52 | 40 | 48 | 0.47 | −0.9 | 3 | 3,479 | nw. | 24 | nw. | 7 | 21 | 9 | 1 | 2.4 | 0.0 | 0.0 |
| Sacramento | 69 | 106 | 117 | 29.87 | 29.94 | −.05 | 63.0 | +0.1 | 92 | 5 | 77 | 42 | 25 | 49 | 35 | 53 | 44 | 57 | 0.47 | −0.4 | 3 | 4,039 | nw. | 28 | sw. | 7 | 27 | 4 | 0 | 1.1 | 0.0 | 0.0 |
| San Francisco | 155 | 208 | 243 | 29.80 | 29.97 | −.04 | 63.2 | +2.7 | 92 | 6 | 72 | 52 | 23 | 55 | 30 | 55 | 50 | 71 | 0.89 | −0.2 | 3 | 3,707 | w. | 25 | nw. | 7 | 21 | 8 | 2 | 3.0 | 0.0 | 0.0 |
| San Jose | 141 | 12 | 110 | 29.83 | 29.98 | | 61.0 | +0.7 | 95 | 6 | 75 | 39 | 26 | 47 | 41 | | | | 0.23 | −0.5 | 4 | 3,239 | nw. | 19 | nw. | 8 | 22 | 8 | 1 | 2.3 | 0 0 | 0.0 |
| *South Pacific Coast Region* | | | | | | | 66.9 | +1.7 | | | | | | | | | | 54 | 0.17 | −0.4 | | | | | | | | | | 1.8 | | |
| Fresno | 327 | 89 | 98 | 29.60 | 29.95 | −.01 | 64.6 | +0.6 | 92 | 6 | 79 | 42 | 26 | 50 | 37 | 53 | 42 | 52 | 0.18 | −0.4 | 1 | 3,290 | nw. | 20 | nw. | 7 | 27 | 4 | 0 | 1.1 | 0.0 | 0.0 |
| Los Angeles | 338 | 159 | 191 | 29.55 | 29.91 | −.04 | 68.7 | +3.4 | 94 | 5 | 79 | 53 | 10 | 58 | 33 | 56 | 47 | 58 | 0.10 | −0.6 | 1 | 3,054 | sw. | 12 | w. | 3 | 25 | 5 | 1 | 1.6 | 0.0 | 0.0 |
| San Diego | 87 | 62 | 70 | 29.81 | 29.90 | −.05 | 64.8 | +1.1 | 89 | 6 | 73 | 52 | 23 | 57 | 27 | 57 | 53 | 71 | 0.22 | −0.3 | 1 | 3,494 | nw. | 18 | nw. | 12 | 21 | 5 | 5 | 2.8 | 0.0 | 0.0 |
| *West Indies* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| San Juan, P. R. | 82 | 9 | 54 | 29.84 | 29.92 | | 80.6 | +0.8 | 93 | 3 | 86 | 73 | 8 | 75 | 17 | | | | 4.08 | −1.8 | 14 | 5,147 | e. | 25 | e. | 13 | 10 | 17 | 4 | 5.0 | 0.0 | 0.0 |
| *Panama Canal* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Balboa Heights | 118 | 6 | 97 | | [1] 29.83 | +.01 | 79.0 | −0.2 | 90 | 29 | 84 | 69 | 11 | 74 | 17 | | | [1] 88 | 8.24 | −1.9 | 22 | 4,697 | s. | 24 | s. | 11 | 0 | 8 | 23 | 8.3 | 0.0 | 0.0 |
| Cristobal | 36 | 6 | 97 | | [1] 29.82 | .00 | 81.4 | +1.6 | 91 | 1 | 87 | 73 | 17 | 76 | 15 | 76 | 74 | [1] 83 | 7.26 | −8.1 | 21 | 4,754 | se. | 22 | sw. | 15 | 0 | 13 | 18 | 7.8 | 0.0 | 0.0 |
| *Alaska* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Fairbanks | 455 | 11 | 44 | [1] 29.39 | [1] 29.92 | | 26.0 | | 44 | 20 | 32 | 4 | 31 | 19 | 25 | 25 | 19 | 69 | 0 94 | | 10 | 1,712 | e. | 16 | e. | 15 | 7 | 6 | 18 | 6.8 | 10.2 | 5.2 |
| Juneau | 80 | 11 | 50 | [1] 29.78 | [1] 29.87 | | 40.3 | | 56 | 30 | 45 | 22 | 19 | 36 | 20 | 37 | 32 | 72 | 14.51 | | 21 | 6,573 | e. | 40 | ne. | 16 | 7 | 3 | 21 | 7.1 | 0.4 | 0.0 |
| *Hawaiian Islands* | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Honolulu | 38 | 86 | 100 | [1] 29.93 | [1] 29.97 | | 78.0 | +1.2 | 84 | 15 | 83 | 70 | 12 | 73 | 14 | 72 | 70 | 78 | 3.73 | +2.2 | 15 | 4,574 | e. | 24 | e. | 23 | 17 | 8 | 6 | 4.1 | 0.0 | 0.0 |

[1] Observations taken hourly.

[2] Pressure not reduced to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, October, 1930*

| Stations | Altitude above mean sea level, Jan. 1, 1919 | Pressure | | | Temperature of the air | | | | | | Precipitation | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Station reduced to mean of 24 hours | Sea level reduced to mean of 24 hours | Departure from normal | Mean max. + mean min. ÷2 | Departure from normal | Mean maximum | Mean minimum | Highest | Lowest | Total | Departure from normal | Total snowfall |
| | *Feet* | *Inches* | *Inches* | *Inches* | *° F.* | *° F.* | *° F.* | *° F.* | *° F.* | *° F.* | *Inches* | *Inches* | *Inches* |
| Cape Race, N. F. | 99 | | | | | | | | | | | | |
| Sydney, C. B. I. | 48 | | | | | | | | | | | | |
| Halifax, N. S. | 88 | | | | | | | | | | | | |
| Yarmouth, N. S. | 65 | | | | | | | | | | | | |
| Charlottetown, P. E. I. | 38 | | | | | | | | | | | | |
| Chatham, N. B. | 28 | | | | | | | | | | | | |
| Father Point, Que. | 20 | | | | | | | | | | | | |
| Quebec, Que. | 296 | 29.75 | 30.08 | +0.08 | 45.9 | +3.5 | 52.4 | 39.4 | 74 | 28 | 1.39 | −1.76 | 0.8 |
| Doucet, Que. | 1,236 | | | | 42.0 | | 53.5 | 30.5 | 79 | 6 | 0.90 | | 1.1 |
| Montreal, Que. | 187 | 29.80 | 30.01 | .00 | 49.3 | +4.5 | 56.0 | 42.7 | 77 | 30 | 1.41 | −1.72 | T. |
| Ottawa, Ont. | 236 | 29.80 | 30.07 | +.06 | 47.9 | +4.1 | 58.1 | 37.7 | 82 | 25 | 1.77 | −0.78 | 0.2 |
| Kingston, Ont. | 285 | 29.77 | 30.08 | +.05 | 49.6 | +2.6 | 56.5 | 42.8 | 72 | 29 | 1.06 | −1.67 | T. |
| Toronto, Ont. | 379 | 29.68 | 30.09 | +.05 | 49.0 | +2.4 | 56.3 | 41.7 | 75 | 27 | 1.87 | −0.49 | 0.2 |
| Cochrane, Ont. | 930 | | | | 42.2 | | 49.6 | 34.7 | 80 | 12 | 1.64 | | 2.5 |
| White River, Ont. | 1,244 | 28.67 | 30.00 | +.02 | 38.6 | +1.5 | 47.4 | 29.9 | 76 | 2 | 1.98 | −0.37 | 3.6 |
| London, Ont. | 808 | | | | 47.9 | | 58.7 | 37.0 | 79 | 21 | 2.85 | | 1.4 |
| Southampton, Ont. | 656 | 29.36 | 30.08 | +.06 | 47.2 | +1.1 | 55.5 | 38.9 | 74 | 27 | 3.44 | +0.27 | 3.9 |
| Parry Sound, Ont. | 688 | 29.37 | 30.07 | +.06 | 46.9 | +3.0 | 54.1 | 39.7 | 75 | 24 | 3.92 | 0.00 | 7.0 |
| Port Arthur, Ont. | 644 | 29.31 | 30.02 | +.04 | 41.7 | +1.8 | 47.6 | 35.8 | 70 | 20 | 3.40 | +0.84 | 0.0 |
| Winnipeg, Man. | 760 | 29.15 | 30.00 | +.02 | 38.9 | −0.2 | 45.9 | 31.9 | 60 | 16 | 3.01 | +1.31 | 1.0 |
| Minnedosa, Man. | 1,690 | 28.15 | 30.00 | +.03 | 35.7 | −2.1 | 44.6 | 26.8 | 64 | 7 | 2.05 | +0.85 | 2.4 |
| Le Pas, Man. | 860 | | | | 32.5 | | 40.4 | 24.7 | 70 | 3 | 1.81 | | 15.7 |
| Qu'Appelle, Sask. | 2,115 | 27.72 | 30.01 | +.04 | 35.1 | −4.3 | 43.6 | 26.5 | 62 | 10 | 1.33 | +0.23 | 9.2 |
| Moose Jaw, Sask. | 1,759 | | | | 37.1 | | 47.0 | 27.1 | 67 | 5 | 1.40 | | 5.1 |
| Swift Current, Sask. | 2,392 | 27.42 | 29.98 | +.01 | 36.5 | −5.6 | 47.1 | 25.9 | 70 | 5 | 1.08 | +0.20 | 7.9 |
| Medicine Hat, Alb. | 2,144 | | | | | | | | | | | | |
| Calgary, Alb. | 3,428 | | | | | | | | | | | | |
| Banff, Alb. | 4,521 | | | | | | | | | | | | |
| Prince Albert, Sask. | 1,450 | 28.42 | 30.02 | +.05 | 34.1 | −3.0 | 41.6 | 26.5 | 71 | −2 | 2.55 | +1.72 | 20.2 |
| Battleford, Sask. | 1,592 | 28.24 | 30.01 | +.04 | 35.0 | −4.6 | 43.6 | 26.4 | 74 | 0 | 1.89 | +1.44 | 15.3 |
| Edmonton, Alb. | 2,150 | | | | | | | | | | | | |
| Kamloops, B. C. | 1,262 | | | | | | | | | | | | |
| Victoria, B. C. | 230 | 29.80 | 30.06 | +.05 | 49.2 | 0.0 | 53.9 | 44.6 | 61 | 36 | 4.79 | +2.42 | 0.0 |
| Barkerville, B. C. | 4,180 | | | | | | | | | | | | |
| Estevan Point, B. C. | 20 | | | | | | | | | | | | |
| Prince Rupert, B. C. | 170 | | | | | | | | | | | | |
| Hamilton, Ber. | 151 | | | | | | | | | | | | |
| **LATE REPORTS, SEPTEMBER, 1930** | | | | | | | | | | | | | |
| Sydney, C. B. I. | 48 | 29.85 | 29.90 | −0.11 | 59.2 | +2.7 | 68.0 | 50.4 | 86 | 39 | 3.74 | +0.46 | 0.0 |
| Halifax, N. S. | 88 | 29.84 | 29.94 | −.10 | 61.0 | +3.4 | 70.1 | 51.9 | 83 | 39 | 0.66 | −3.05 | 0.0 |
| Yarmouth, N. S. | 65 | 29.84 | 29.91 | −.14 | 59.0 | +2.9 | 66.6 | 51.4 | 78 | 42 | 0.51 | −3.10 | 0.0 |
| Charlottetown, P. E. I. | 38 | 29.80 | 29.84 | −.17 | 59.9 | +2.6 | 66.5 | 53.3 | 84 | 46 | 2.12 | −1.28 | 0.0 |
| Chatham, N. B. | 28 | 29.79 | 29.82 | −.18 | 57.0 | +1.6 | 66.4 | 47.7 | 83 | 37 | 2.98 | +0.27 | 0.0 |
| Doucet, Que. | 1,236 | | | | 49.6 | | 59.1 | 40.2 | 78 | 26 | 5.30 | | 0.0 |
| Medicine Hat, Alb. | 2,144 | 27.46 | 29.69 | −.23 | 56.6 | +1.6 | 69.0 | 44.3 | 89 | 33 | 3.35 | +2.17 | T. |
| Calgary, Alb. | 3,428 | 26.38 | 29.93 | +.01 | 51.2 | +1.4 | 63.6 | 38.9 | 84 | 26 | 1.37 | +0.01 | 4.2 |
| Banff, Alb. | 4,521 | 25.36 | 29.90 | −.03 | 48.9 | +3.1 | 60.8 | 37.0 | 78 | 22 | 1.47 | −0.20 | 2.9 |
| Edmonton, Alb. | 2,150 | 27.60 | 29.87 | −.03 | 50.5 | +1 2 | 61.6 | 39.4 | 81 | 23 | 1.25 | −0.08 | T. |
| Kamloops, B. C. | 1,262 | 28.65 | 29.93 | −.04 | 59.1 | +1.7 | 69.3 | 48.9 | 85 | 31 | 0.50 | −0.35 | 0.0 |
| Estevan Point, B. C. | 20 | | | | 53.8 | | 59.7 | 48.0 | 66 | 38 | 6.16 | | 0.0 |
| Prince Rupert, B. C. | 170 | | | | 54.2 | | 61.6 | 46.9 | 76 | 38 | 9.53 | | 0.0 |

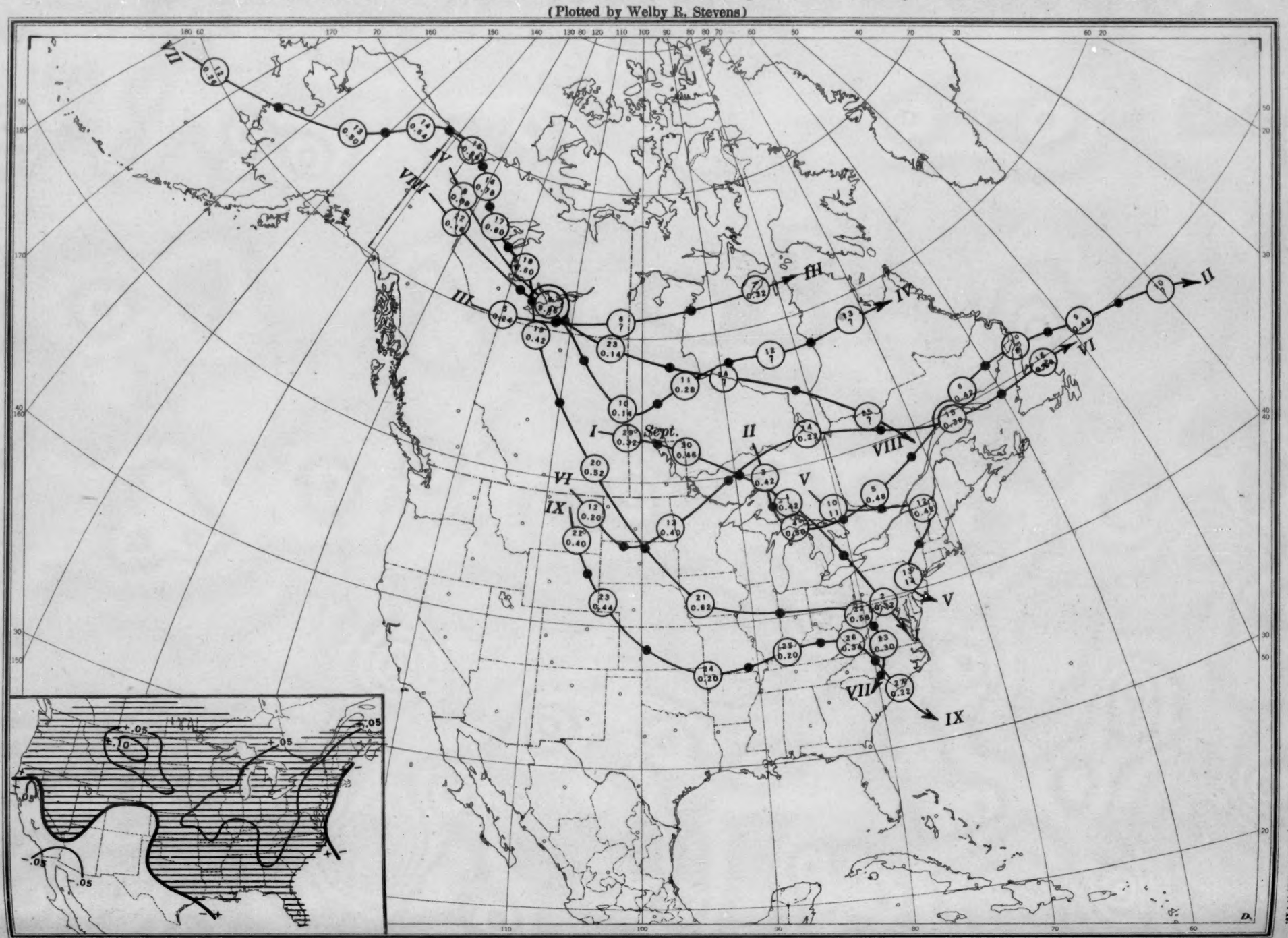
Chart I.—Departure (°F.) of the Mean Temperature from the Normal, October, 1930

**Chart I. Departure (°F.) of the Mean Temperature from the Normal, October, 1930**

UNIV. OF MICH.

**Chart II. Tracks of Centers of Anticyclones, October, 1930. (Inset) Departure of Monthly Mean Pressure from Normal**

(Plotted by Welby R. Stevens)




Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

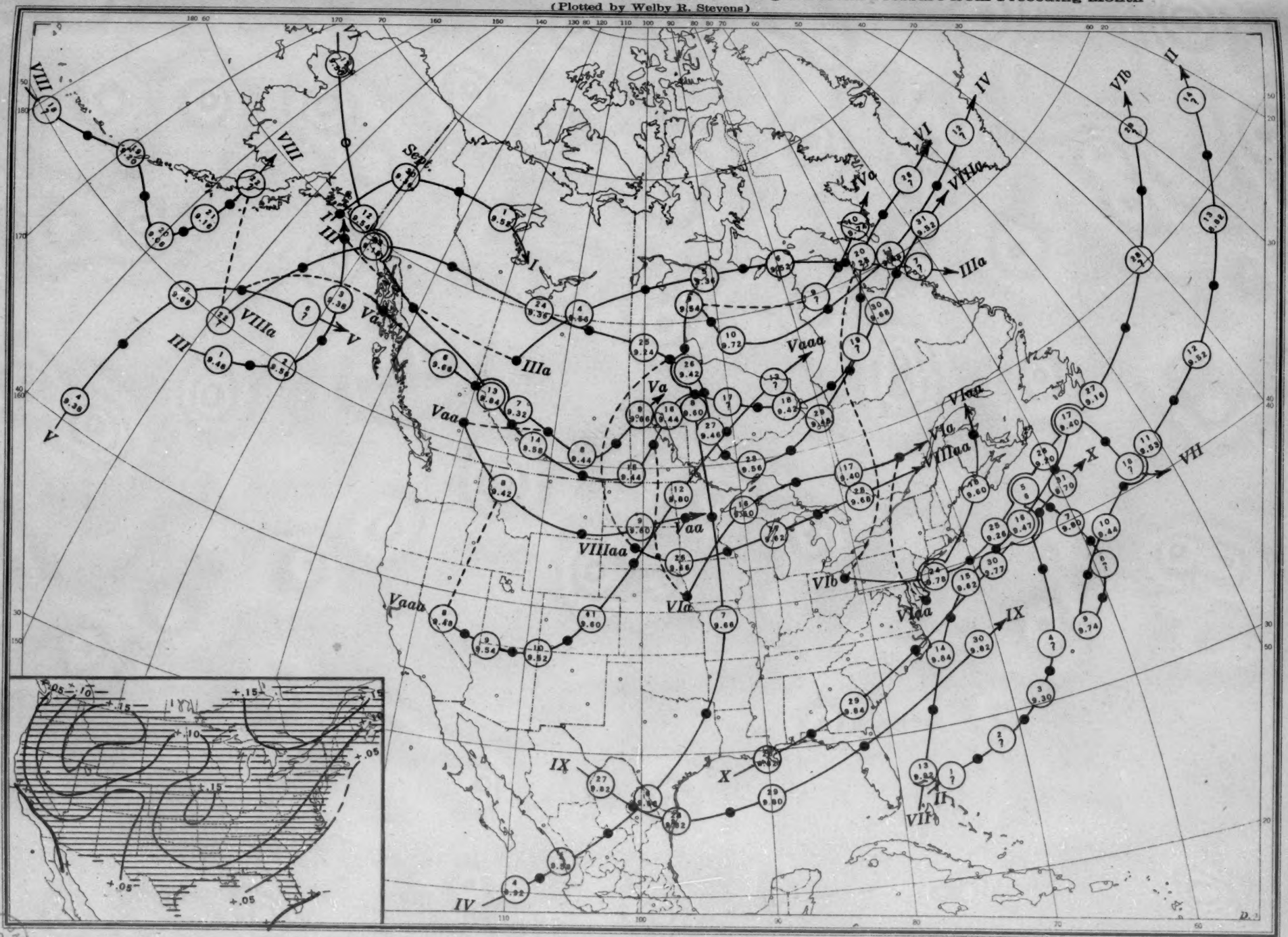


**Chart III. Tracks of Centers of Cyclones, October, 1930. (Inset) Change in Mean Pressure from Preceding Month**

Circle indicates position of anticyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of anticyclone at 8 p. m. (75th meridian time).

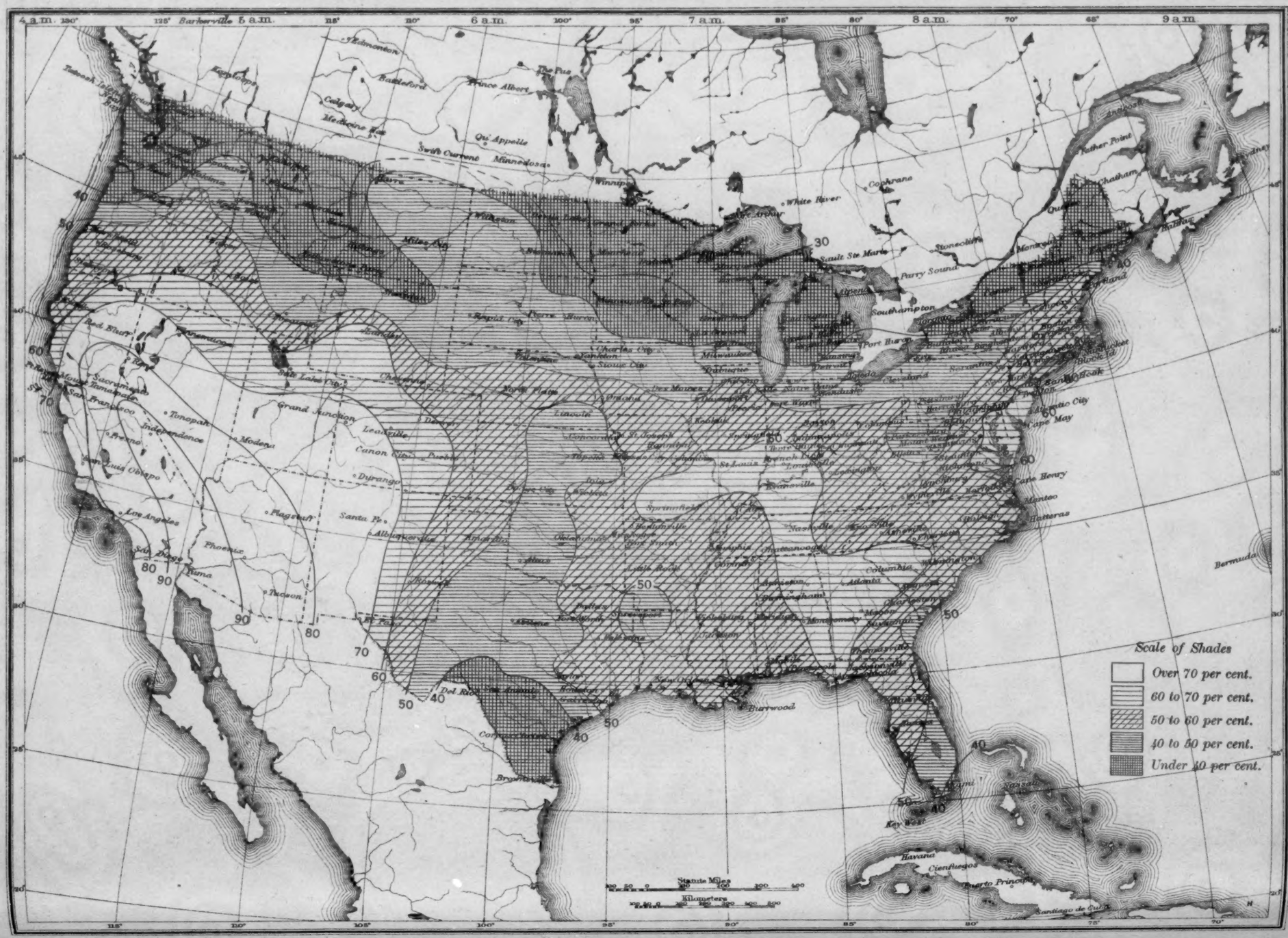
**Chart III. Tracks of Centers of Cyclones, October, 1930.** (Inset) **Change in Mean Pressure from Preceding Month**

(Plotted by Welby R. Stevens)




Circle indicates position of cyclone at 8 a. m. (75th meridian time), with barometric reading. Dot indicates position of cyclone at 8 p. m. (75th meridian time).

## Chart IV. Percentage of Clear Sky between Sunrise and Sunset, October, 1930

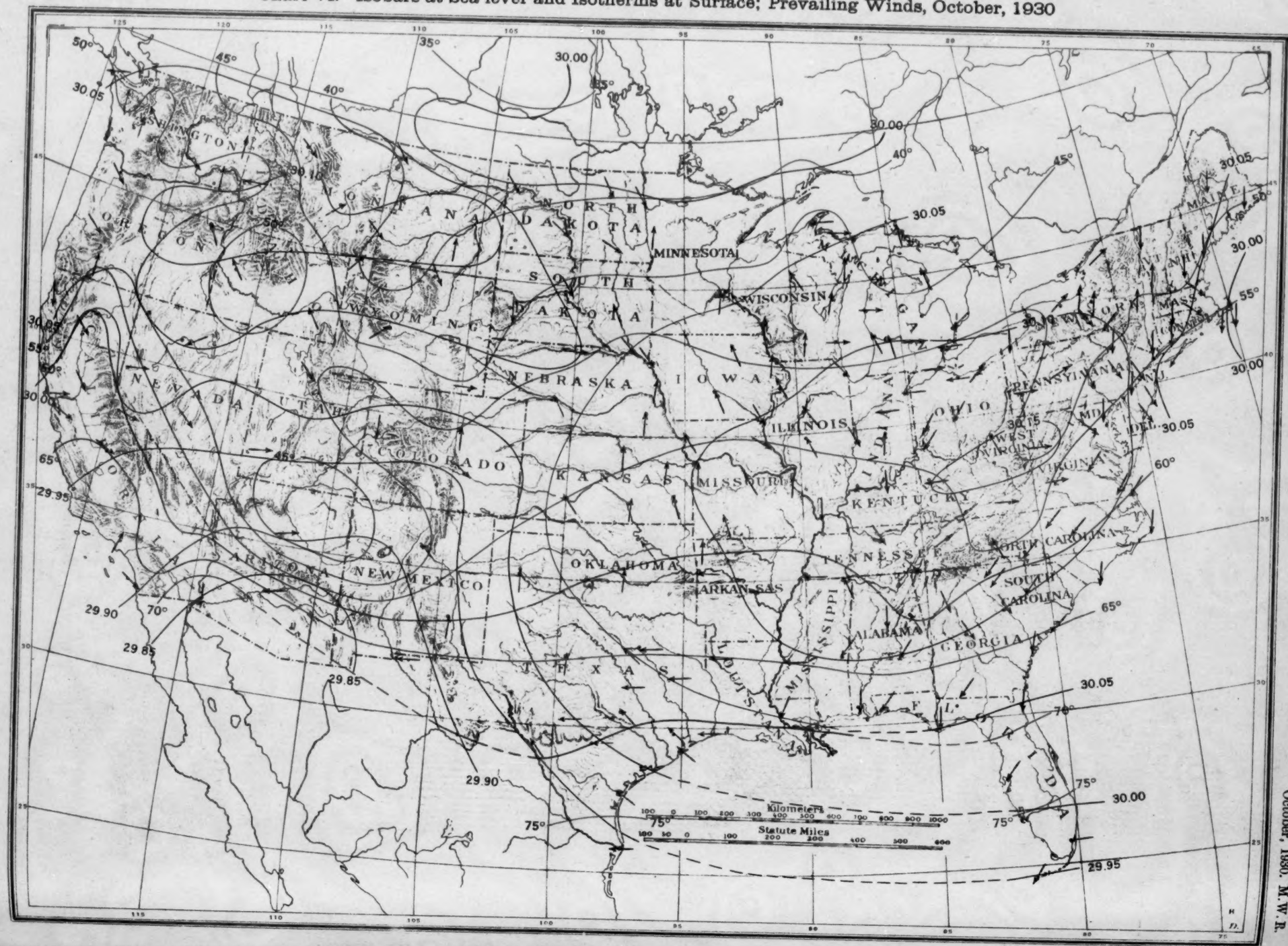





## Chart V. Total Precipitation, Inches, October, 1930. (Inset) Departure of Precipitation from Normal

Chart V. Total Precipitation, Inches, October, 1930. (Inset) Departure of Precipitation from Normal

## Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, October, 1930






## Chart VIII. Weather Map of North Atlantic Ocean, October 4, 1930

(Plotted by F. A. Young)

## Chart VIII. Weather Map of North Atlantic Ocean, October 4, 1930

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

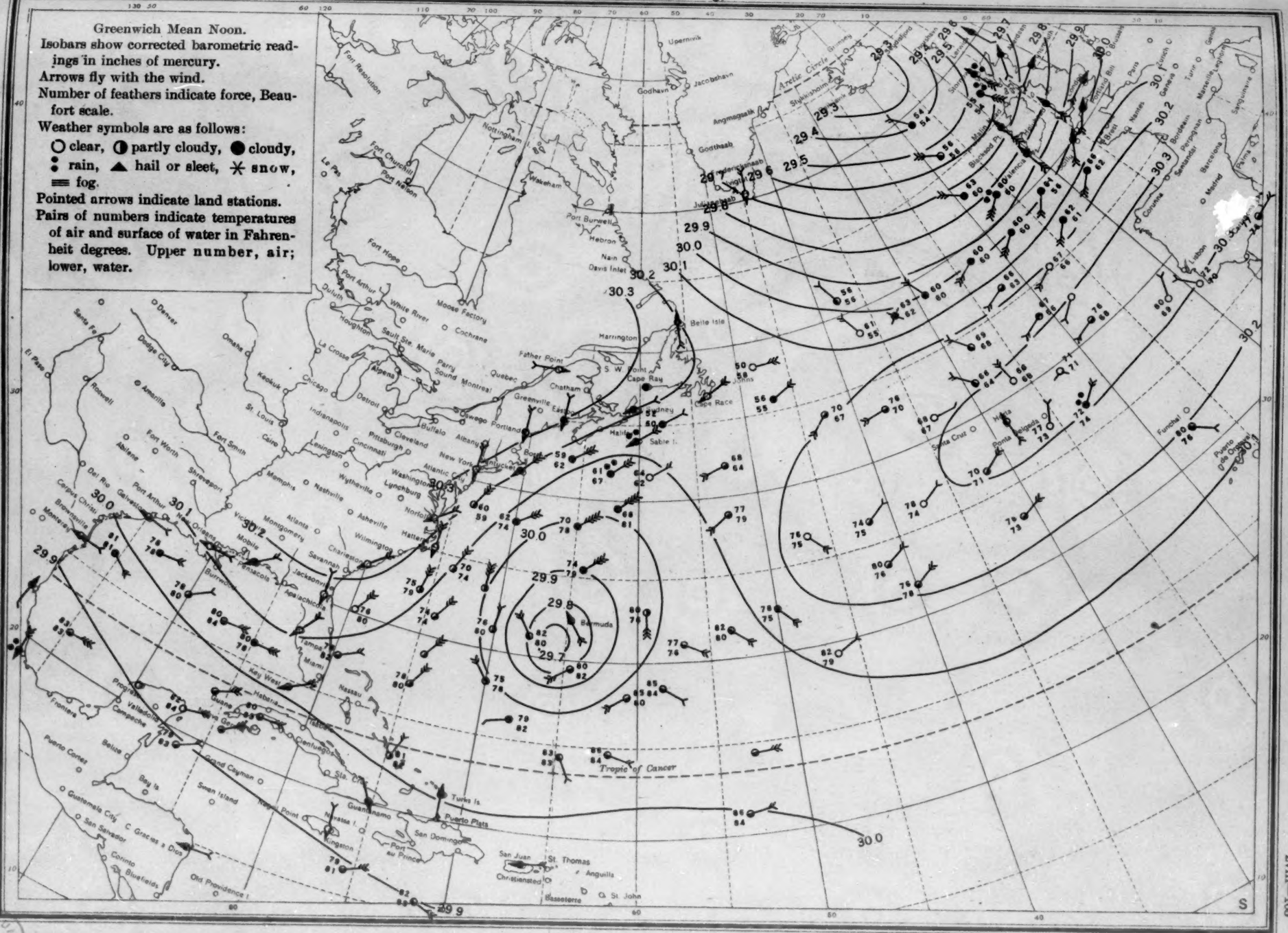
Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

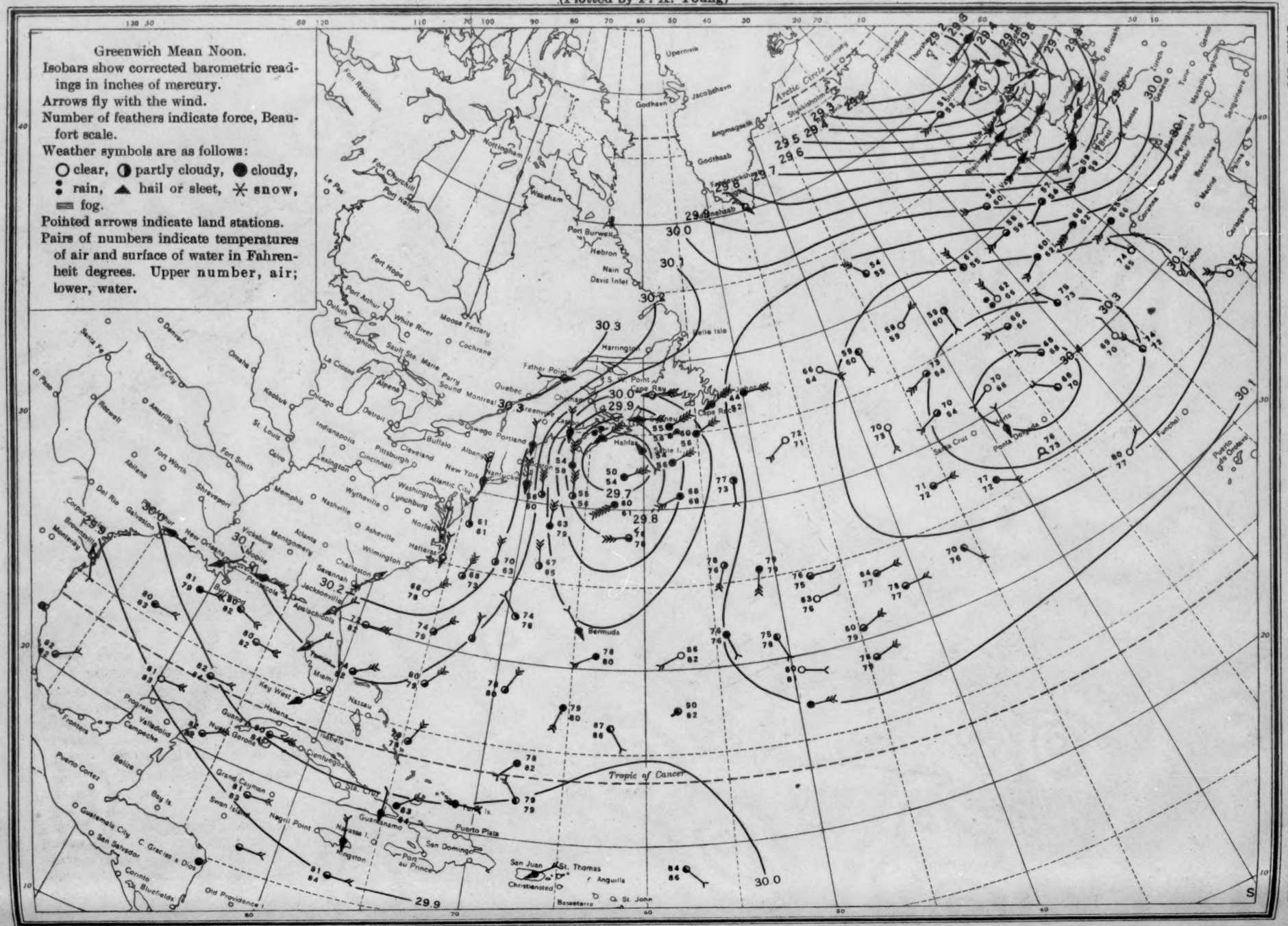
Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.



## Chart IX. Weather Map of North Atlantic Ocean, October 5, 1930

(Plotted by F. A. Young)



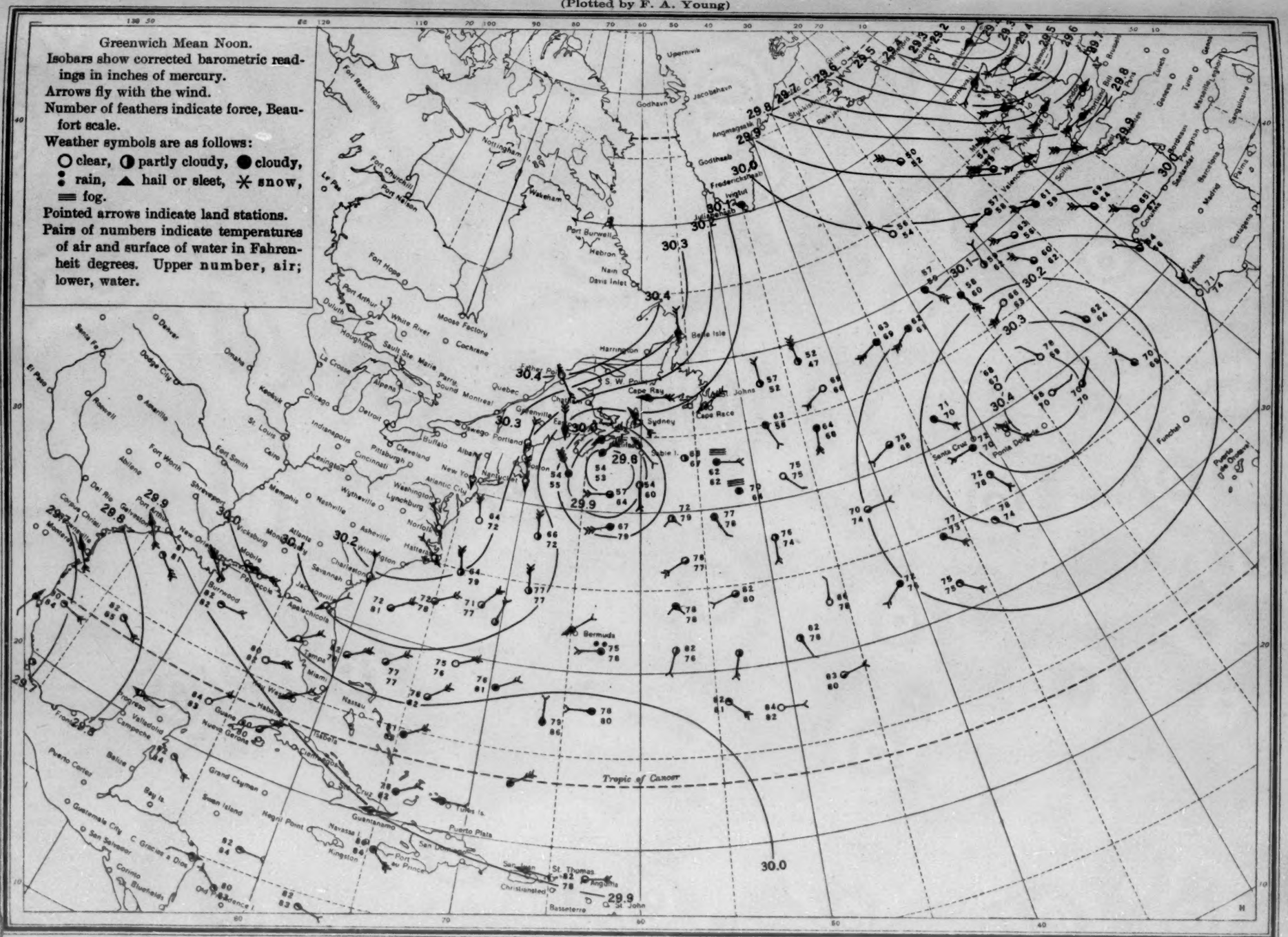



## Chart X. Weather Map of North Atlantic Ocean, October 6, 1930

(Plotted by F. A. Young)

## Chart X. Weather Map of North Atlantic Ocean, October 6, 1930

(Plotted by F. A. Young)


Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy,
rain, hail or sleet, snow,
fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Tropic of Cancer

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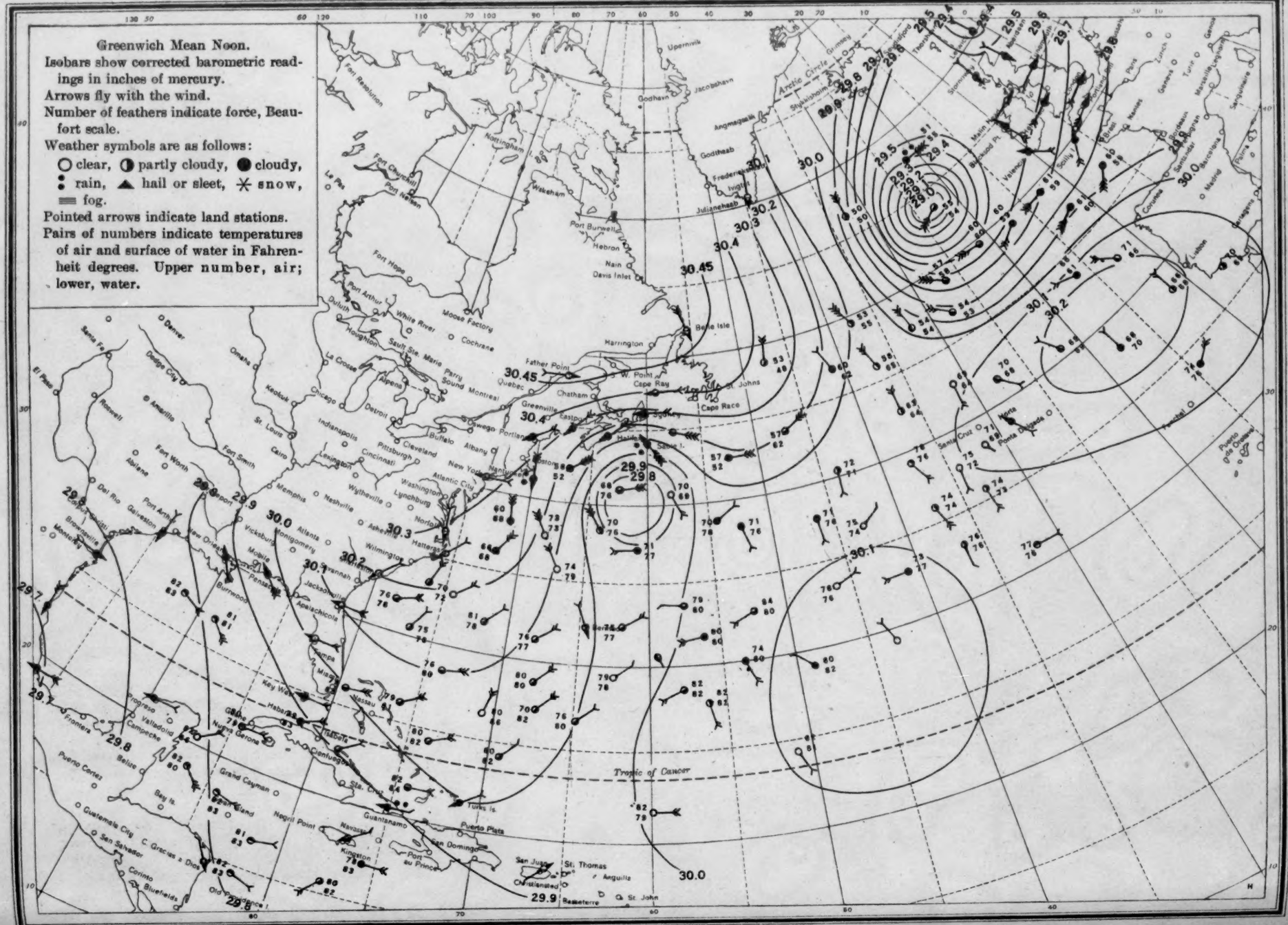
# Chart XI. Weather Map of North Atlantic Ocean, October 7, 1930

(Plotted by F. A. Young)